KANSAS-LOWER REPUBLICAN BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody / Assessment Unit: Delaware River Watershed above Perry Lake
Water Quality Impairment: Total Phosphorus

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Delaware River **Counties** Atchison, Brown, Jackson, Jefferson, Nemaha

HUC 8: **10270103**
HUC10 (HUC12**)**: **01** (01, 02, 03, 04, 05, 06, 07, 08, 09, 10)
02 (01, 02, 03, 04, 05)
03 (01, 02, 03, 04, 05, 06, 07, 08)
04 (01, 08)

Ecoregion: Loess and Glacial Drift Hills (47i)

Drainage Area: Approximately 741.1 square miles

Main Stem Water Quality Limited Segments:

Water Quality Limited Segments Covered Under this TMDL *(designated uses for main stem and tributary segments are detailed in **Table 1**)*:

Station	***Main Stem Segment***	***Tributaries***	
SC554	Delaware R (13)	Nebo Cr (48)	
		Catamount Cr (49)	
	Delaware R (14)		
	Delaware R (15)	Little Grasshopper Cr (16)	
		Negro Cr (43)	
	Delaware R (17)	Gregg Cr (24)	
		Muddy Cr (25)	
		Muddy Cr (26)	
		Wolfley Cr (27)	
		Plum Cr (36)	
		Cedar Cr (37)	
		Squaw Cr (38)	
		Barnes Cr (39)	
	Delaware R (21)		
	Delaware R (22)		
	Delaware R (23)		
SC603	Grasshopper Cr (18)	Clear Cr (19)	Brush Cr (44)
		Mission Cr (40)	
		Otter Cr (41)	
		Grasshopper Cr (20)	

SC604	Elk Cr (29)	Unnamed Stream (31) Banner Cr (45) Bills Cr (47)	
	Elk Cr (30)		
SC686	Straight Cr (28)	Spring Cr (42)	Mosquito Cr (602)

Table 1. Designated uses for main stem and tributary segments in the watershed (Kansas Department of Health and Environment, 2013).

Stream	Segment #	Expected Aquatic Life	Contact Recreation	Domestic Supply	Food Procurement	Ground Water Recharge	Industrial Water Use	Irrigation Use	Livestock Watering Use
HUC8: 10270103									
Delaware R	**13**	**E**	**C**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Nebo Cr	48	E	B	Y	N	Y	Y	Y	Y
Catamount Cr	49	E	C	N	Y	Y	N	Y	Y
Delaware R	**14**	**E**	**C**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Delaware R	**15**	**E**	**C**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Little Grasshopper Cr	16	E	b	N	N	Y	N	Y	Y
Negro Cr	43	E	b	N	Y	Y	N	Y	Y
Delaware R	**17**	**E**	**B**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Delaware R	**21**	**E**	**C**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Delaware R	**22**	**E**	**B**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Delaware R	**23**	**E**	**b**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Gregg Cr	24	E	C	N	Y	N	N	N	N
Muddy Cr	25	E	C	Y	Y	Y	Y	Y	Y
Muddy Cr	26	E	b	Y	Y	Y	Y	Y	Y
Wolfley Cr	27	E	b	Y	N	Y	Y	Y	Y
Plum Cr	36	E	b	Y	N	Y	Y	Y	Y
Cedar Cr	37	E	b	Y	Y	Y	Y	Y	Y
Squaw Cr	38	E	b	N	Y	N	N	N	N
Barnes Cr	39	E	b	N	N	N	N	N	N
Grasshopper Cr	**18**	**E**	**b**	**Y**	**N**	**Y**	**Y**	**Y**	**Y**
Clear Cr	19	E	B	N	N	N	N	N	N
Brush Cr	44	E	b	N	N	N	N	N	N
Grasshopper Cr	20	E	b	Y	Y	Y	Y	Y	Y
Mission Cr	40	E	B	Y	Y	Y	Y	Y	Y
Otter Cr	41	E	b	N	Y	Y	N	Y	Y
Elk Cr	**29**	**E**	**C**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Unnamed Stream	31	E	b	Y	N	Y	Y	Y	Y
Banner Cr	45	E	B	Y	Y	Y	Y	Y	Y
Bills Cr	47	E	b	Y	Y	Y	Y	Y	Y
Elk Cr	**30**	**E**	**C**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Straight Cr	**28**	**E**	**b**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Spring Cr	42	E	C	Y	Y	Y	Y	Y	Y
Mosquito Cr	602	E	C	Y	N	Y	Y	Y	Y

Y=use is designated; N=use is not designated; E=Expected aquatic life; A, B, C=Primary Contact Recreation; a, b=Secondary Contact Recreation

Impaired Use: Expected Aquatic Life, Contact Recreation, Domestic Water Supply.

303(d) Listings: Kansas Stream segments monitored by station SC554 **(Figure 1)**, Delaware River near Half Mound, are cited as impaired by Total Phosphorus (TP) (Cat. 5) in 2010, 2012, 2014, 2016 & 2018 and impaired by Biology (Cat. 5) in 2012, 2014, 2016 & 2018.

Kansas Stream segments monitored by station SC603, Grasshopper Creek near Muscotah, are cited as impaired by TP (Cat. 5) in 2008, 2010, 2012, 2014, 2016 & 2018.

Kansas Stream segments monitored by station SC604, Elk Creek near Larkinburg, are cited as impaired by TP (Cat. 5) in 2008, 2010, 2012, 2014, 2016 & 2018 for the Kansas-Lower Republican Basin.

Kansas Stream segments monitored by station SC686, Straight Creek near Larkinburg, are cited as unimpaired by TP for the Kansas-Lower Republican Basin.

Water Quality Criteria:

***Nutrients -- Narrative*:**
The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life (K.A.R. 28-16-28e(d)(2)(A)).

The introduction of plant nutrients into surface waters designated for primary or secondary contact recreational use shall be controlled to prevent the development of objectionable concentrations of algae or algal by-products or nuisance growths of submersed, floating, or emergent aquatic vegetation (K.A.R. 28-16-28e(d)(7)(A)).

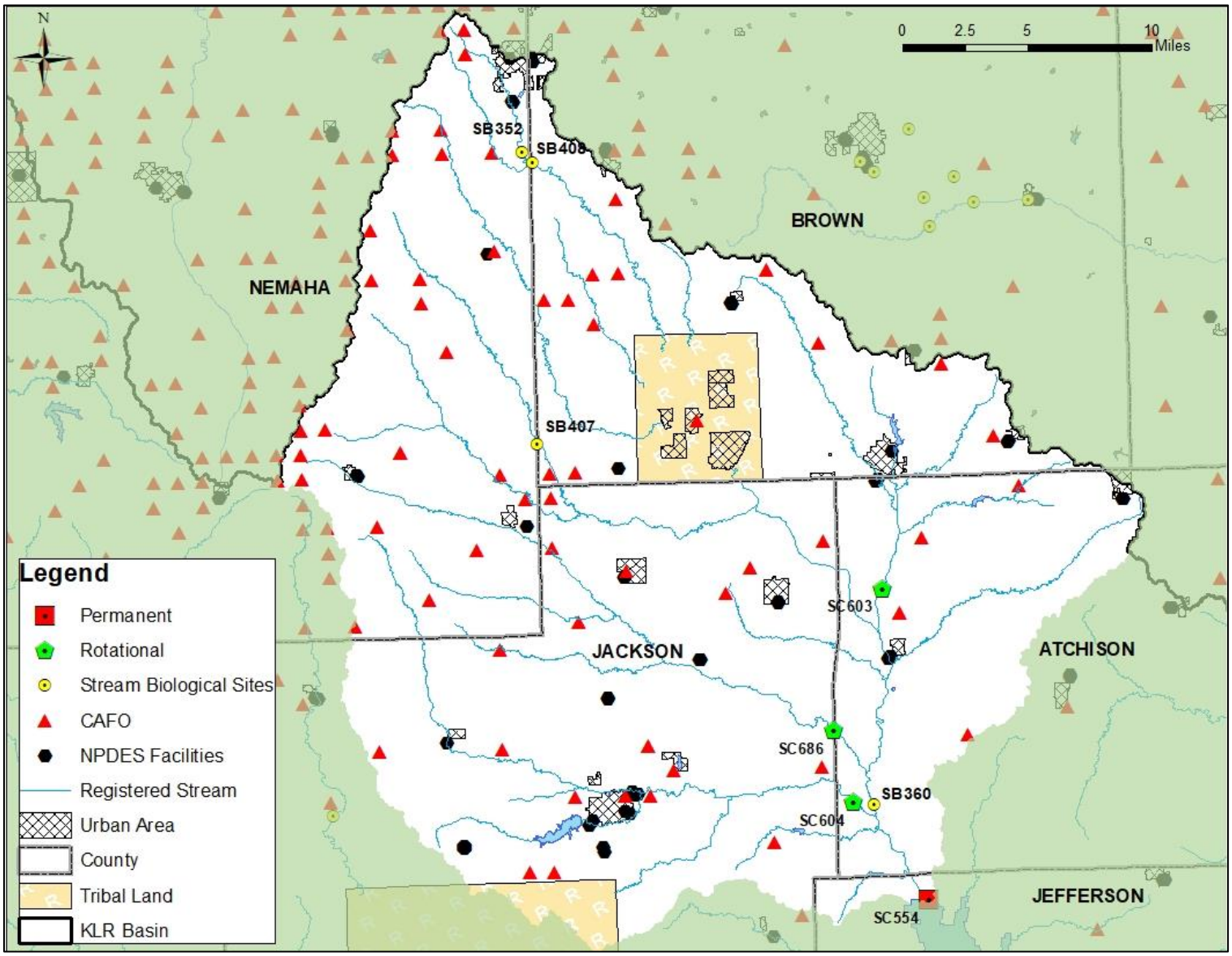
The introduction of plant nutrient into surface waters designated for domestic water supply use shall be controlled to prevent interference with the production of drinking water (K.A.R. 28-16-28e(d)(3)(D)).

Taste-producing and odor-producing substances of artificial origin shall not occur in surface waters at concentrations that interfere with the production of potable water by conventional water treatment processes, that impart an unpalatable flavor to edible aquatic or semiaquatic life or terrestrial wildlife, or that result in noticeable odors in the vicinity of surface waters (K.A.R. 28-16-28e(b)(7)).

Dissolved Oxygen -- Numeric:
The concentration of dissolved oxygen in surface waters shall not be lowered by the influence of artificial sources of pollution. The Dissolved Oxygen criterion is 5 mg/L (K.A.R. 28-16-28e(e)).

pH – Numeric: Artificial sources of pollution shall not cause the pH of any surface water outside of a zone of initial dilution to be below 6.5 and above 8.5 (K.A.R. 28-16-28e: Tables of Numeric Criteria).

Figure 1. Map of contributing area for KDHE stream chemistry stations SC554, SC603, SC604 and SC686.



2. CURRENT WATER QUALITY CONDITIONS AND DESIRED ENDPOINT

Level of Support for Designated Uses under the 2018 303(d) List: Phosphorus levels in Delaware River near Half Mound (SC554), Grasshopper Creek near Muscotah (SC603), and Elk Creek near Larkinburg (SC604) are consistently high. Excessive nutrients are not being controlled and are thus impairing aquatic life, domestic water supply, and contact recreation

uses. The ultimate endpoint of this Total Maximum Daily Load (TMDL) will be to achieve the Kansas Surface Water Quality Standards by eliminating excessive primary productivity and impairment to aquatic life, recreation, and domestic water supply associated with excessive phosphorus.

Station Location and Period of Record

Stream Chemistry (SC) Monitoring Station

SC554: Active, permanent station on the Delaware River near Half Mound, located on County Road Bridge, 0.5 mile west of Half Mound. Sampled quarterly in the period of record from April 4, 1990 to October 22, 2018.

SC603: Active, rotational station on Grasshopper Creek near Muscotah, located on K-9 Highway Bridge, 2.5 miles north and 0.25 mile west of Muscotah. Sampled quarterly every 4 years from the period of record from February 19, 1992 to November 1, 2016.

SC604: Active, rotational station on Elk Creek near Larkinburg, located on K-116 Highway Bridge, 0.75 mile east of Larkinburg. Sampled quarterly every 4 years from the period of record from March 17, 1993 to November 1, 2016.

SC686: Active, rotational station on Straight Creek near Larkinburg, located on County Road Bridge, 3.0 miles north of Larkinburg. Sampled quarterly every 4 years from the period of record from January 22, 1997 to November 1, 2016.

Stream Biology (SB) Monitoring Stations

SB352: Active station on Delaware River at rest stop park at intersection of Highway 36 and Acorn Road. Period of record: August 20, 2013 to August 3, 2017.

SB360: Active Station on the Delaware River on K-116 Highway Bridge, 0.5 mile west of Arrington. Period of record: June 26, 1996 to August 3, 2017.

SB407: Active Station on Muddy Creek at County Road Br. 2.75 miles south of Granada. Period of record: March 25, 1990 to October 10, 1994.

SB408: Active Station on the Delaware River at dead end road 3 miles south and 0.25 mile west of Sabetha. Period of record: March 25, 1992 to October 10, 1994.

Streamflow Gage

U.S. Geological Survey 06890100: Delaware River near Muscotah. Period of record: January 1, 1990 to December 31, 2018.

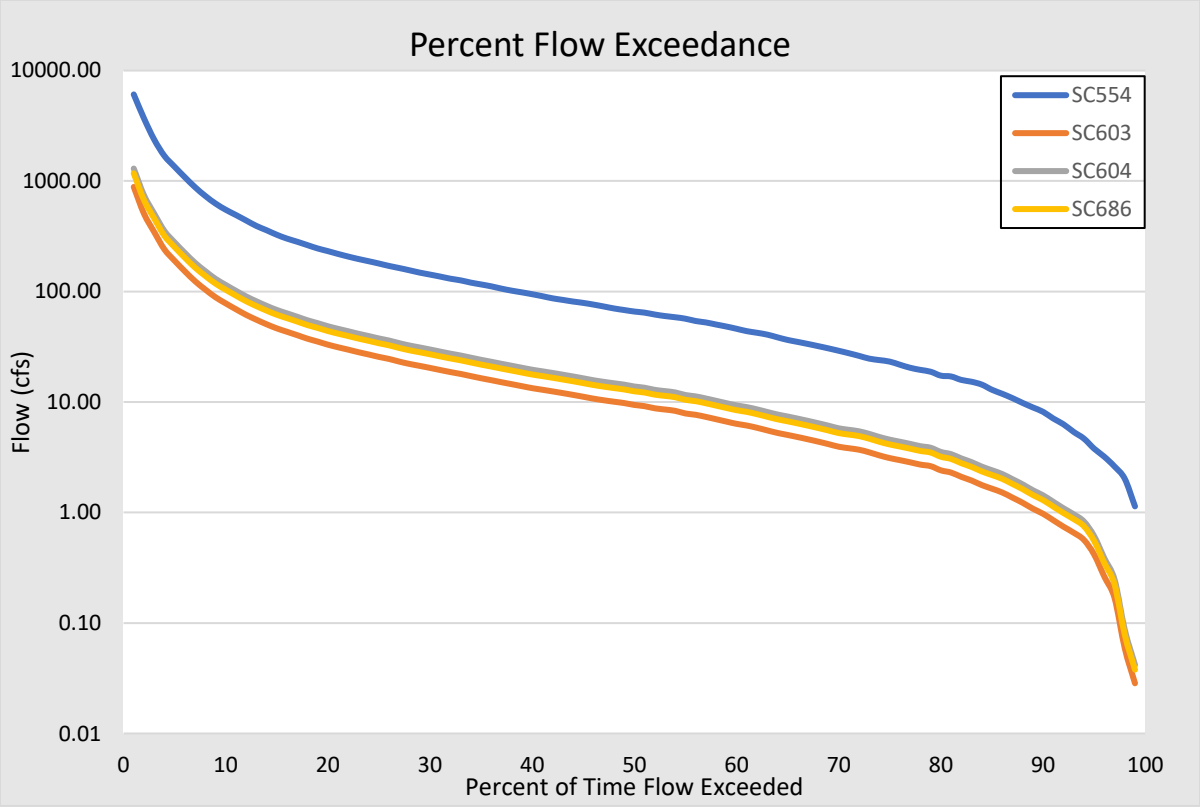
Hydrology:

Streamflow conditions at SC554, SC603, SC604 and SC686 were analyzed using U.S. Geological Survey (USGS) streamgage data from Delaware River near Muscotah (06890100). This USGS gage has streamflow data available for the period of record from January 1, 1990 to December 31, 2018. Flow at SC554 was based on a regression analysis between USGS 06890100 on Delaware River near Muscotah and flows for the Delaware River in Atchison County (segment 1027010313) in the USGS Scientific Investigations Report 2004-5033 (Perry, et. al., 2004). A watershed ratio was performed on this regression for flow at the stream chemistry site. Flow at SC603, SC604, and SC686 were based on a watershed ratio with USGS 06890100 on the Delaware River near Muscotah (**Table 2**). **Figure 2** displays the flow duration curves for SC554, SC603, SC604, and SC686.

Table 2. Kansas Department of Health and Environment (KDHE) estimated flow conditions at stream chemistry (SC) stations on the Delaware River near Half Mound (SC554) Grasshopper Creek near Muscotah (SC603), Elk Creek near Larkinburg (SC604), and Straight Creek near Larkinburg (SC686) and monitored flow conditions at U.S. Geological Survey (USGS) gages.

Stream	Station	Contributing Drainage Area (mi^2)	Mean Flow (CFS)	Percent Flow Exceedance (CFS)				
				90%	75%	50%	25%	10%
Delaware River	KDHE SC554	741.1	345.9	4.74	19.08	61.45	170.30	523.30
Grasshopper Creek	KDHE SC603	94.3	51.70	0.97	3.11	9.41	25.60	78.01
Elk Creek	KDHE SC604	138.4	75.90	1.43	4.56	13.81	37.60	114.60
Straight Creek	KDHE SC686	125.4	68.70	1.29	4.13	12.50	34.00	103.80
Delaware River	USGS 6890100	431	236.4	4.43	14.20	43.00	117.00	357.00

Figure 2. Estimated flow duration curve for Kansas Department of Health and Environment stations Delaware River near Half Mound (SC554) Grasshopper Creek near Muscotah (SC603), Elk Creek near Larkinburg (SC604), and Straight Creek near Larkinburg (SC686) U.S. Geological Survey gaged site located in the Delaware River near Muscotah (06890100).



Long term estimated flows for the Delaware River and its tributaries can be found in **Table 3** (Perry et. al, 2004). The main tributaries to the Delaware River are Elk Creek, Grasshopper Creek, and Straight Creek.

Table 3. U.S. Geological Survey (USGS) long term estimated flows for the Delaware River and its tributaries (Perry et.al, 2004). Description: AT-Atchison; BR- Brown; JA- Jackson; JF- Jefferson; NM- Nemaha

Stream	KSWR CUSEGA Number	County	Drainage Area (mi^2)	Mean Flow (CFS)	Flow Exceedance (%)					2-year Peak (CFS)
					90%	75%	50%	25%	10%	
Plum Cr	1027010336	BR	68.6	43.3	0.10	0.86	5.49	19.4	59.1	4,280
Cedar Cr	1027010337	NM	11.0	6.70	0	0.01	0.31	1.89	7.10	1,140
Squaw Cr	1027010338	BR	12.8	9.55	0	0.01	0.83	3.55	11.5	1,400
Barnes Cr	1027010339	NM	13.3	9.56	0	0.01	1.09	4.00	12.0	1,430
Craig Cr	1027010324	BR	68.6	43.3	0.10	0.86	5.49	19.4	59.1	4,280
Delaware R	1027010323	BR	149	89.5	0.48	3.14	12.7	42.2	129	6,550
Barnes Cr	1027010339	NM	13.3	9.56	0	0.01	1.09	4.00	12.0	1,430
Muddy Cr	1027010326	BR; JA; NM	42.7	27.4	0.04	0.24	3.33	12.1	36.4	3,170
Muddy Cr	1027010325	JA	108	67.0	0.25	1.90	9.06	31.2	95.1	5,360
Wolfley Cr	1027010327	JA; NM	43.7	29.1	0.04	0.37	3.79	13.4	39.6	3,180
Delaware R	1027010322	BR; JA	153	91.7	0.51	3.30	13.2	43.5	133	6,590
Delaware R	1027010321	AT; JA	280	165	2.04	8.14	26.8	82.7	254	9,010
Clear Cr	1027010319	AT	25.1	17.6	0.01	0.03	1.50	6.55	21.5	2,080
Brush Cr	1027010344	AT	5.56	3.91	0	0	0	0.60	3.58	867
Grasshopper Cr	1027010320	AT	73.2	48.5	0.12	0.78	5.54	20.7	65.2	5,000
Mission Cr	1027010340	AT; BR	12.0	9.30	0	0.01	0.85	3.55	11.3	1,370
Otter Cr	1027010341	AT	33.5	23.6	0.02	0.05	2.45	9.63	30.2	3,520
Grasshopper Cr	**1027010318**	**106**	**68.5**	**0.24**	**1.61**	**8.30**	**30.0**	**94.6**	**5,950**	**106**
Little Grasshopper Cr	1027010316	AT	45.4	32.5	0.04	0.34	3.95	14.6	44.2	3,280
Negro Cr	1027010343	AT; JA	23.9	17.0	0.01	0.03	1.67	6.72	21.2	2,040
Delaware R	**1027010317**	**AT**	**388**	**229**	**4.18**	**13.2**	**39.5**	**117**	**361**	**11,400**
Delaware R	**1027010315**	**AT**	**470**	**280**	**6.20**	**18.0**	**51.0**	**146**	**450**	**12,500**
Mosquito Cr	10270103602	JA; NM	18.0	14.2	0	0	1.79	6.47	18.9	1,680
Spring Cr	1027010342	JA	58.1	40.3	0.01	0.77	5.51	19.4	56.7	2,680
Straight Cr	**1027010328**	**JA; NM**	**28.4**	**21.1**	**0**	**0**	**2.49**	**9.32**	**27.9**	**2,240**
Elk Cr	**1027010330**	**JA**	**49.4**	**34.2**	**0**	**0.41**	**4.22**	**15.5**	**46.5**	**4,460**
Unnamed Stream	1027010331	JA	4.50	3.59	0	0	0.19	0.99	3.80	786
Bills Cr	1027010347	JA	20.8	15.6	0	0	1.61	6.38	19.7	1,730
Elk Cr	**1027010329**	**JA**	**101**	**65.1**	**0.02**	**1.44**	**8.30**	**29.9**	**91.0**	**6,070**
Delaware R	**1027010314**	**AT**	**587**	**308**	**6.14**	**18.0**	**54.4**	**157**	**485**	**12,100**
Nebo Cr	1027010348	AT; JA	15.4	11.7	0	0	1.12	4.58	14.4	1,600
Catamount Cr	1027010349	AT; JF	12.3	9.82	0	0	1.19	4.20	12.4	1,430
Delaware R	**1027010313**	**AT; JF**	**761**	**28**	**6.03**	**17.8**	**59.1**	**171**	**536**	**11,000**

Annual mean flows at all gages are higher than median flows, with the highest mean flows occurring in 1993 and highest median flows occurring in 2008 (**Figures 3-6**). The lowest annual mean and median flows for all gages occurred in 2003. Annual flows generally coincide with National Oceanic and Atmospheric Administration (NOAA) annual total precipitation from Holton station USC00143759, though it does not tend to coincide with peak annual flows, possibly due to variability in rainfall intensity across the watersheds. Monthly, the highest mean and median flows occurred in May for all gages (**Figures 7-10**). Seasonally, high flows occur in spring (April through June) and low flows occur in winter (November through March). Spring flows are skewed by high flow events, likely due to precipitation and runoff events, and coincide with the higher mean flows in May. The mean during the summer-fall season is higher than the winter season, indicating isolated, seasonal runoff events are likely occurring in the watershed. (**Figure 11**).

Figure 3. Estimated annual mean and median flows for the Delaware River near Half Mound (SC554) based upon U.S. Geological Survey gaged site located in the Delaware River near Muscotah (06890100) and annual total precipitation at National Oceanic and Atmospheric Administration station in Holton, KS (USC00143759).

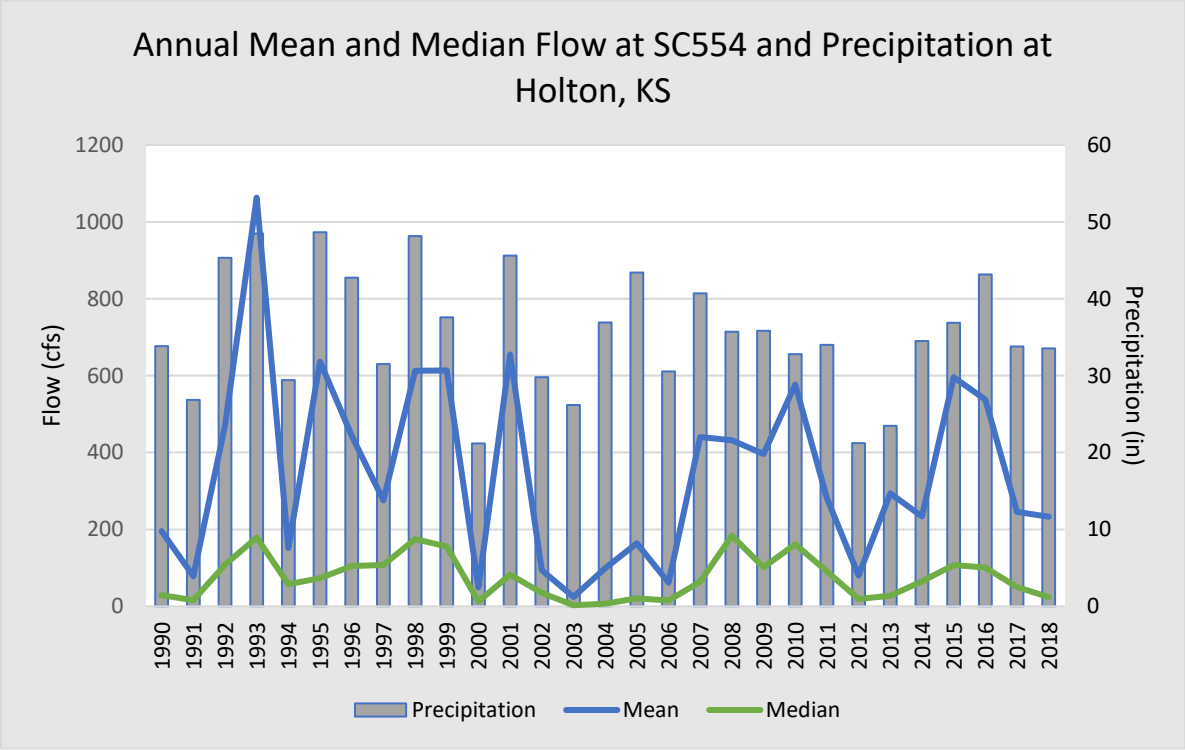


Figure 4. Estimated annual mean and median flows for Grasshopper Creek near Muscotah (SC603) based upon U.S. Geological Survey gaged site located in the Delaware River near Muscotah (06890100) and annual total precipitation at National Oceanic and Atmospheric Administration station in Holton, KS (USC00143759).

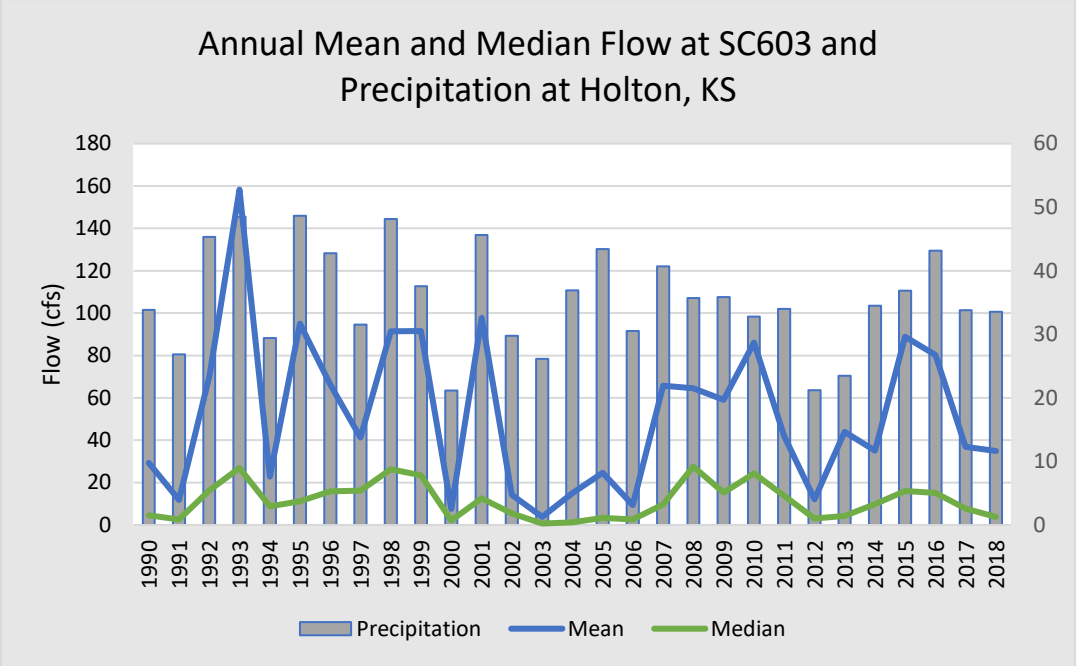


Figure 5. Estimated annual mean and median flows for Elk Creek near Larkinburg (SC604) based upon U.S. Geological Survey gaged site located in the Delaware River near Muscotah (06890100) and annual total precipitation at National Oceanic and Atmospheric Administration station in Holton, KS (USC00143759).

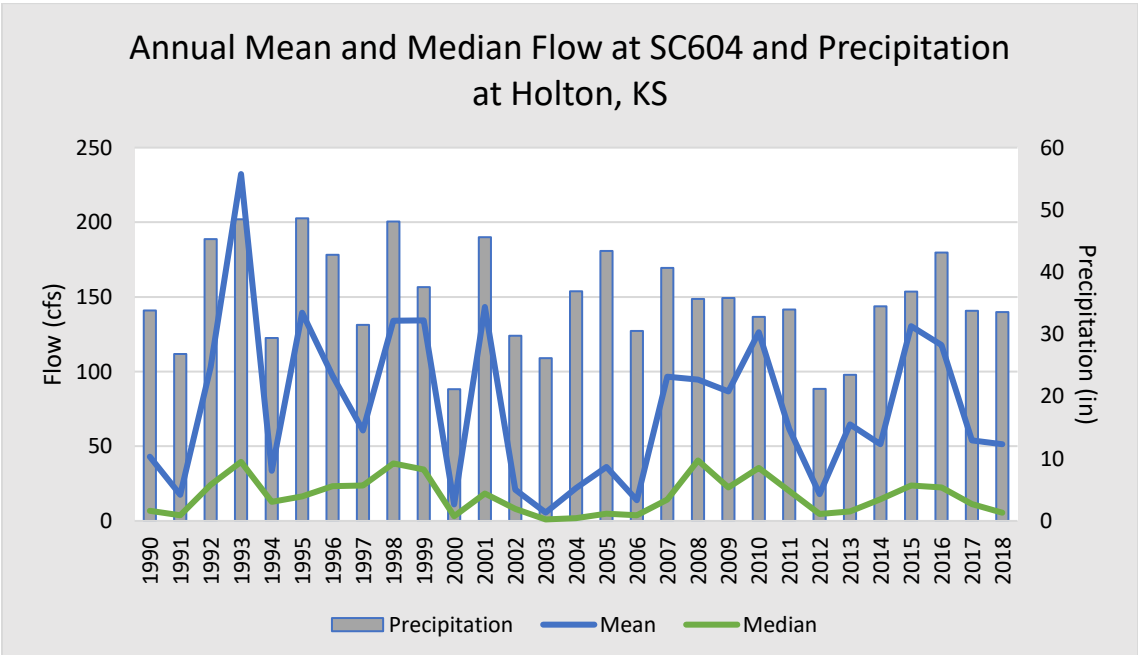


Figure 6. Estimated annual mean and median flows for Straight Creek near Larkinburg (SC686) based upon U.S. Geological Survey gaged site located in the Delaware River near Muscotah (06890100) and annual total precipitation at National Oceanic and Atmospheric Administration station in Holton, KS (USC00143759).

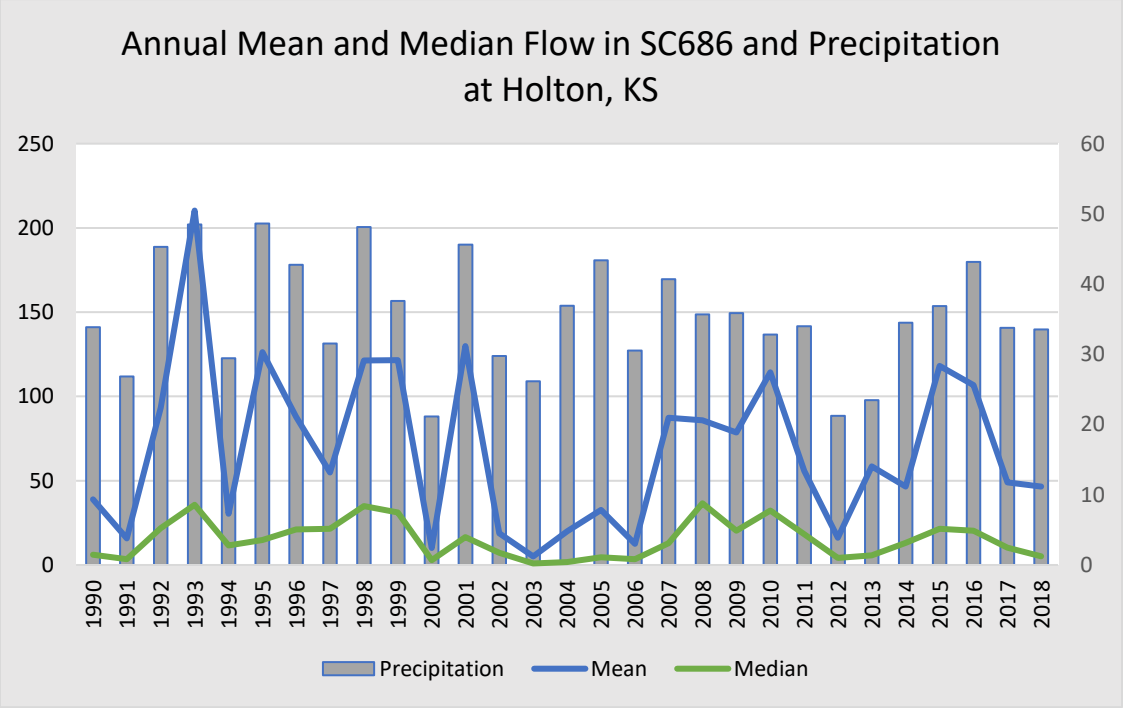


Figure 7. Estimated monthly mean and median flows for the Delaware River near Half Mound (SC554) from 1/1/1990-12/31/2018.

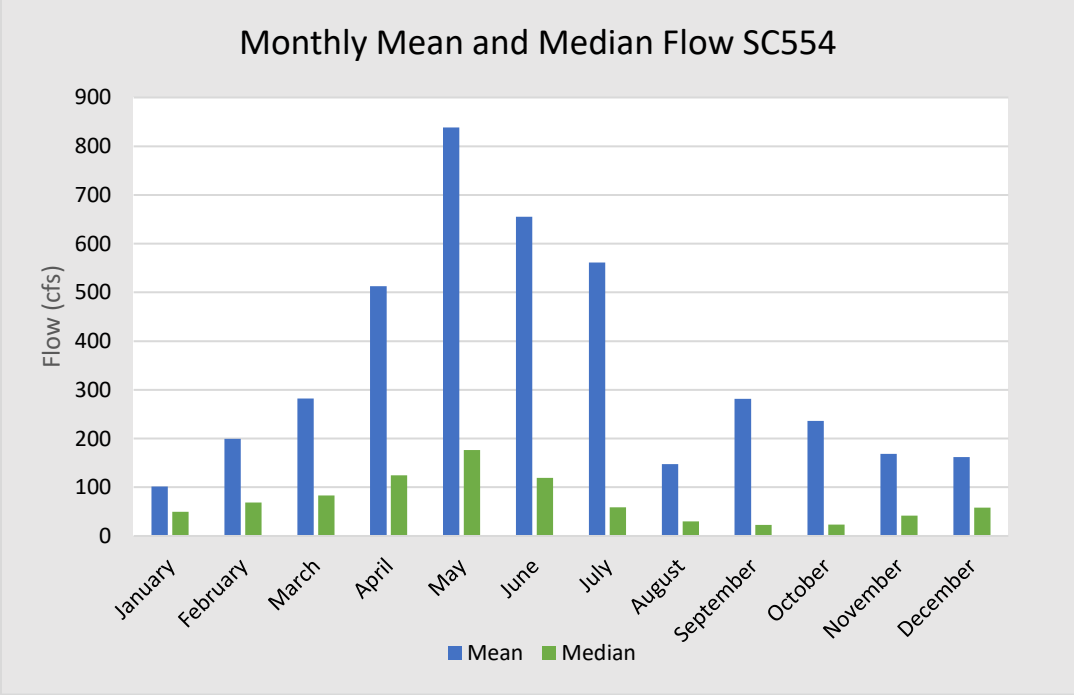


Figure 8. Estimated monthly mean and median flows for Grasshopper Creek near Muscotah (SC603) from 1/1/1990-12/31/2018.

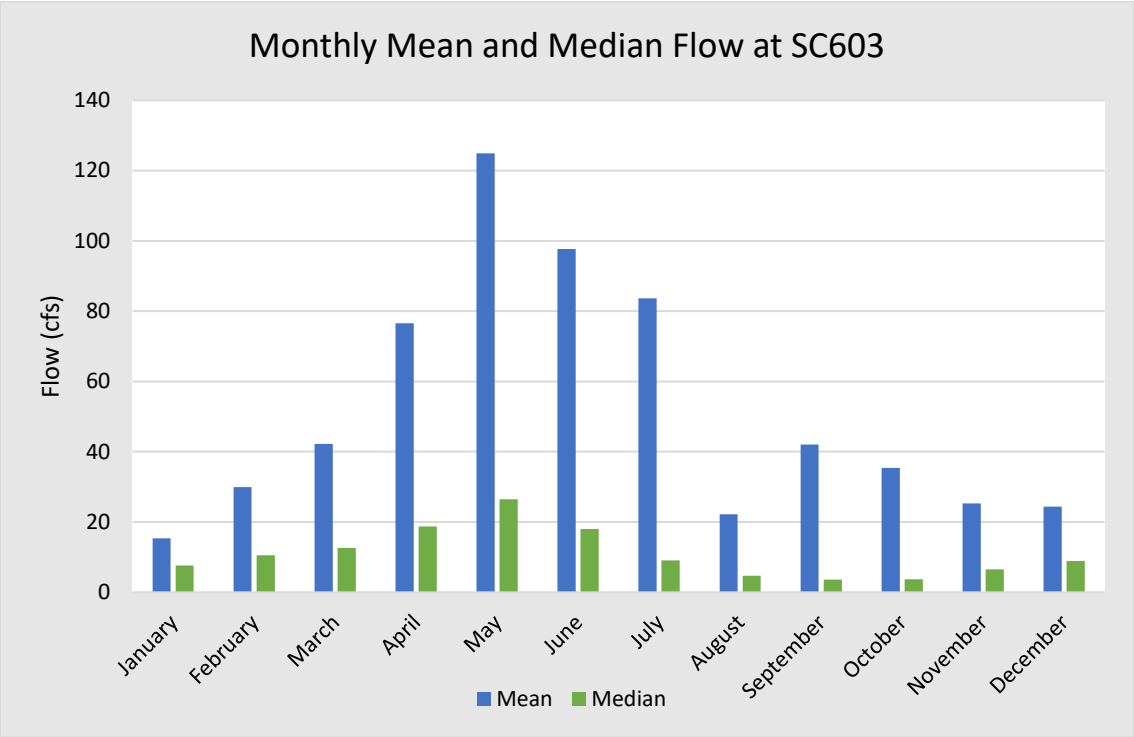


Figure 9. Estimated monthly mean and median flows for Elk Creek near Larkinburg (SC604) from 1/1/1990-12/31/2018.

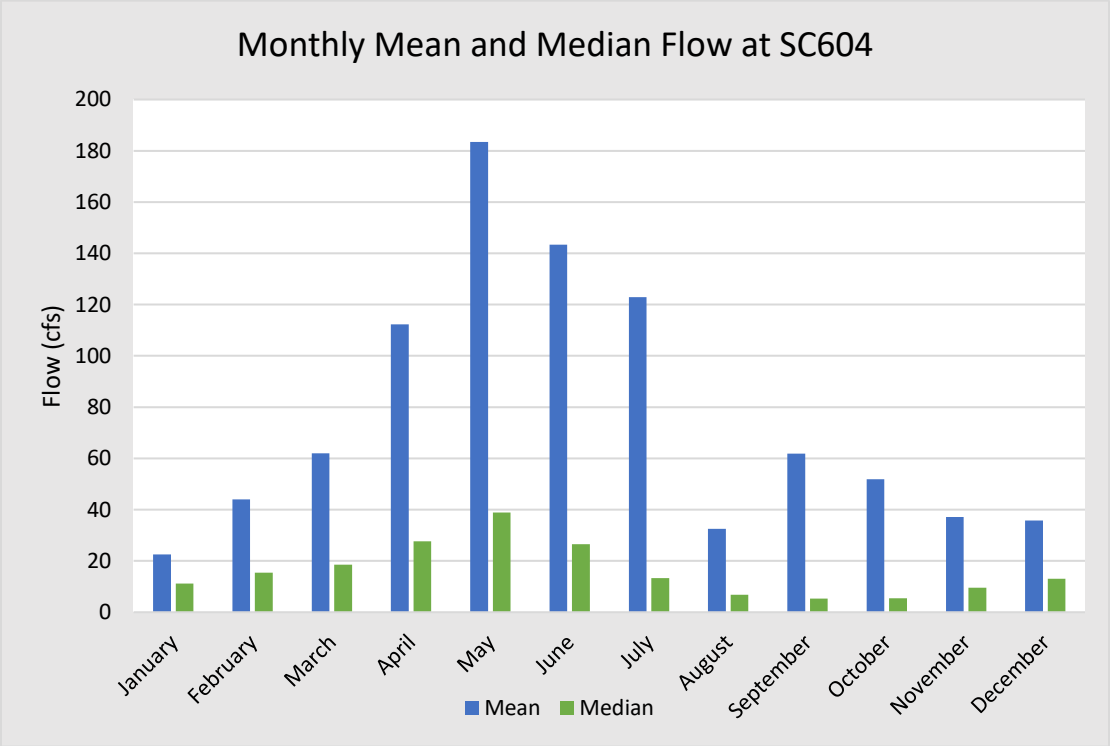


Figure 10. Estimated monthly mean and median flows for Straight Creek near Larkinburg (SC604) from 1/1/1990-12/31/2018.

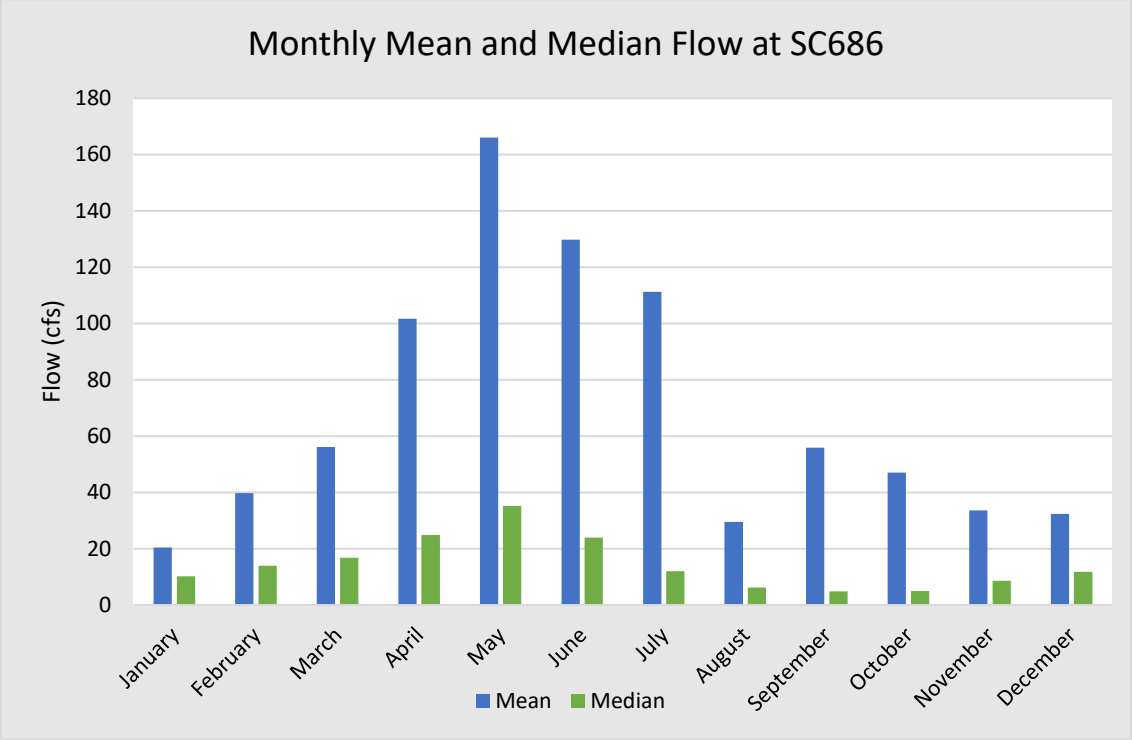
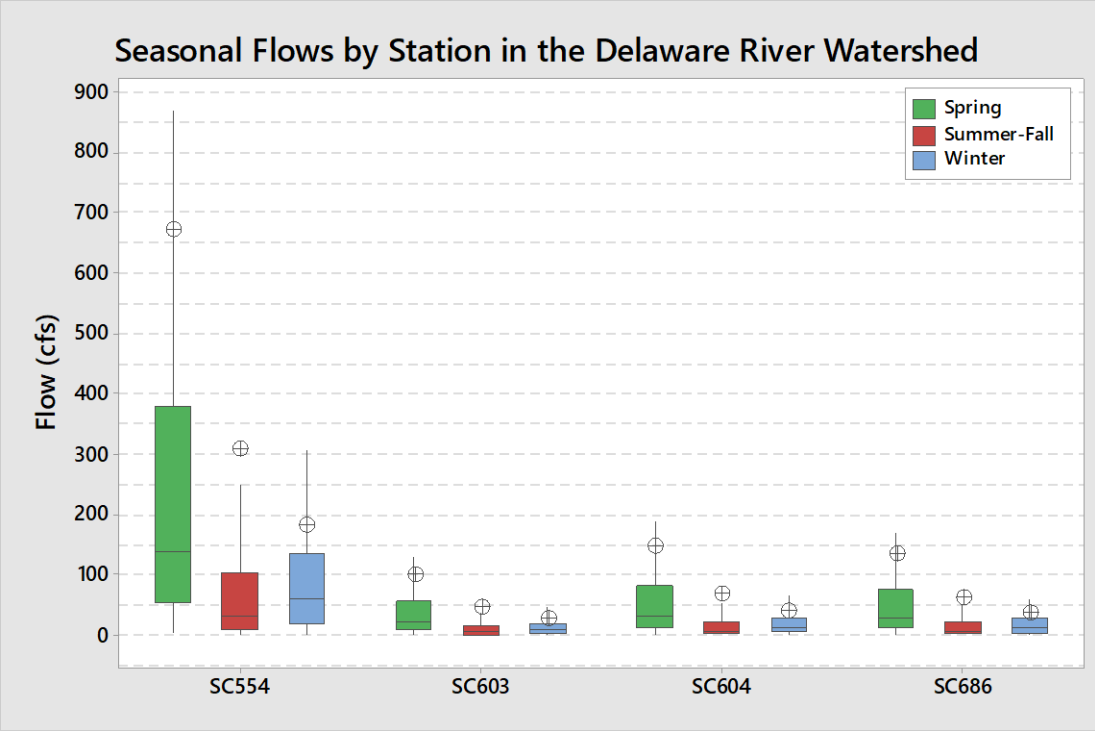


Figure 11. Flow by season for Delaware River near Half Mound (SC554) Grasshopper Creek near Muscotah (SC603), Elk Creek near Larkinburg (SC604), and Straight Creek near Larkinburg (SC686).



Total Phosphorus

Overall, mean total phosphorus (TP) concentrations are highest in the Delaware River at SC554 with a concentration of 0.311 mg/L (**Figure 12; Table 5**). The highest median TP concentration is in Elk Creek at SC604 with a concentration of 0.240 mg/L. TP concentrations are lower in Grasshopper Creek (SC603) with mean and median concentrations of 0.276 and 0.217 mg/L, respectively. The Straight Creek (SC686) station, while considered unimpaired for TP, is a monitored station within the watershed and therefore, it is considered in this analysis for comparison purposes. Total phosphorus concentrations are lowest in Straight Creek (SC686), with a mean concentration of 0.238 mg/L and a median concentration of 0.180 mg/L. This TMDL will serve to protect the Straight Creek watershed by establishing a TP endpoint equivalent to the current median concentration in the stream. TP concentrations seen at upstream stations SC603, SC604, and SC686 are primary contributors to the loads and concentrations seen at SC554.

Figure 12. Total phosphorus for the Delaware River (SC554), Grasshopper Creek (SC603), Elk Creek (SC604), and Straight Creek (SC686).

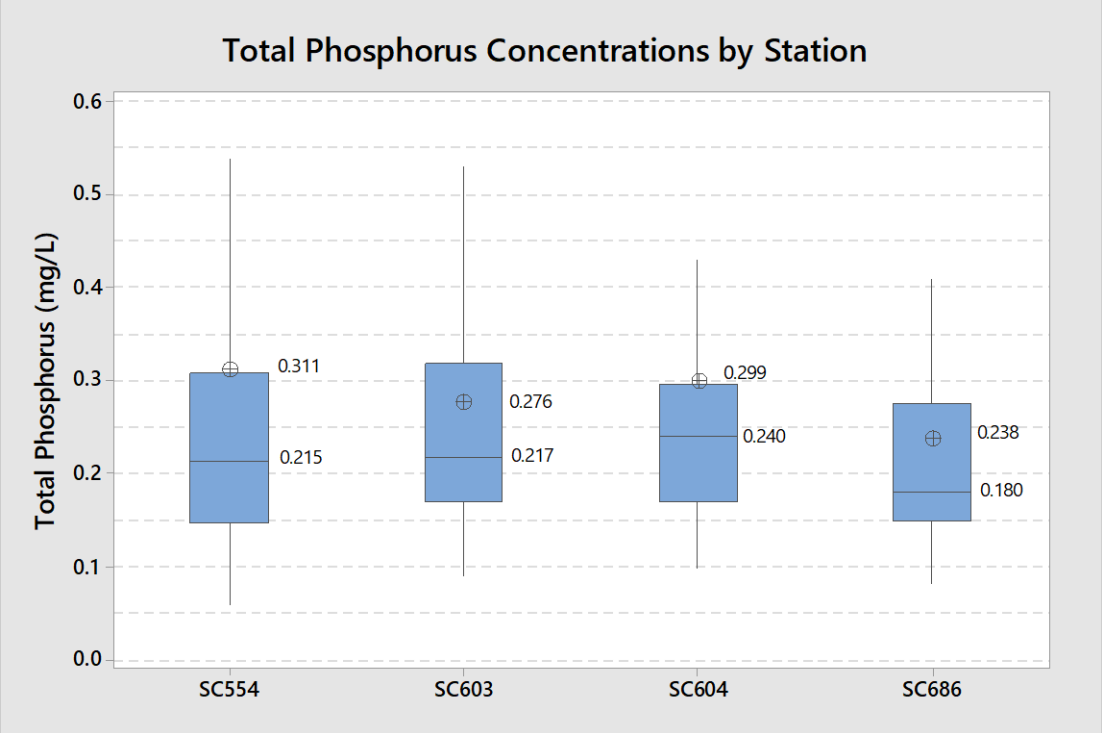


Table 5. Total phosphorus mean, median, and sample number (N) in the Delaware River Watershed above Perry Lake, March 4, 1990 to October 22, 2018.

Station	Stream	Sampling Frequency	Mean	Median	N
SC554	Delaware River near Half Mound	Permanent	0.311	0.215	172
SC603	Grasshopper Creek near Muscotah	Rotational	0.276	0.217	120
SC604	Elk Creek near Larkinburg	Rotational	0.299	0.240	43
SC686	Straight Creek near Larkinburg	Rotational	0.238	0.180	37

For the Delaware River (SC554) the high annual mean of 0.978 mg/L occurred in 1999 and the high annual median of 0.498 mg/L occurred in 2008. Grasshopper Creek (SC603) recorded its high annual mean and median concentration in 1992 with 0.447 mg/L and 0.395 mg/L, respectively. Elk Creek's (SC604) highest annual mean and median concentration occurred in 1993 with 0.538 mg/L and 0.425 mg/L, respectively. In 2008, Straight Creek (SC686) recorded a high annual median TP concentration of 0.314 mg/L and a high annual mean of 0.457 mg/L. As **Table 6** shows, higher TP mean and median concentrations generally occurred during the 1990-1999 period of record at all stations, except for the unimpaired station in Straight Creek (SC686). Low annual TP mean and median concentrations generally coincided with the following low flow years; 2004 for the Delaware River (SC554), with a mean of 0.168 mg/L and median of 0.147 mg/L; 2000 at Grasshopper Creek (SC603), with a mean of 0.198 mg/L and median of 0.165 mg/L; 2012 in Elk Creek (SC604), with a mean of 0.170 mg/L and a median of 0.174 mg/L; and 2004 in Straight Creek (SC686), with a mean of 0.128 mg/L and a median of 0.104 mg/L.

Table 6. Annual total phosphorus mean and median concentrations in the Delaware River Watershed above Perry Lake, March 4, 1990 to October 22, 2018. Values with no data are denoted with a – symbol.

Year	SC554 Delaware R			SC603 Grasshopper Cr			SC604 Elk Cr			SC686 Straight Cr		
	Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N
1990	0.660	0.210	5	-	-	-	-	-	-	-	-	-
1991	0.259	0.250	6	-	-	-	-	-	-	-	-	-
1992	0.418	0.290	5	0.447	0.395	6	-	-	-	-	-	-
1993	0.352	0.255	6	-	-	-	0.538	0.425	6			
1994	0.273	0.190	12	-	-	-	-	-	-	-	-	-
1995	0.434	0.221	8	-	-	-	-	-	-	-	-	-
1996	0.235	0.240	7	0.248	0.200	31	-	-	-	-	-	-
1997	0.234	0.233	6	0.273	0.217	25	0.255	0.250	7	0.176	0.175	7
1998	0.289	0.240	5	0.271	0.210	29	-	-	-	-	-	-
1999	0.978	0.175	6	-	-	-	-	-	-	-	-	-
2000	0.175	0.195	6	0.198	0.165	6	-	-	-	-	-	-
2001	0.241	0.240	5	-	-	-	0.256	0.243	7	0.262	0.239	8
2002	0.237	0.228	6	-	-	-	-	-	-	-	-	-
2003	0.179	0.168	8	-	-	-	-	-	-	-	-	-
2004	0.168	0.147	7	0.258	0.270	6	0.291	0.230	7	0.128	0.104	7
2005	0.226	0.218	6	-	-	-	-	-	-	-	-	-
2006	0.179	0.188	7	-	-	-	-	-	-	-	-	-
2007	0.337	0.347	7	-	-	-	-	-	-	-	-	-
2008	0.387	0.498	5	0.353	0.294	8	0.336	0.315	7	0.457	0.314	6
2009	0.335	0.266	7	-	-	-	-	-	-	-	-	-
2010	0.203	0.207	5	-	-	-	-	-	-	-	-	-
2011	0.239	0.204	5	-	-	-	-	-	-	-	-	-
2012	0.220	0.149	6	0.289	0.274	4	0.170	0.174	5	0.183	0.133	4
2013	0.523	0.345	5	-	-	-	-	-	-	-	-	-
2014	0.426	0.270	5	-	-	-	-	-	-	-	-	-

Year	SC554 Delaware R			SC603 Grasshopper Cr			SC604 Elk Cr			SC686 Straight Cr		
	Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N
2015	0.175	0.155	4	-	-	-	-	-	-	-	-	-
2016	0.250	0.245	4	0.264	0.270	5	0.208	0.205	4	0.222	0.190	5
2017	0.247	0.250	4	-	-	-	-	-	-	-	-	-
2018	0.220	0.215	4	-	-	-	-	-	-	-	-	-
1990-1999	**0.413**	**0.237**	**66**	**0.310**	**0.214**	**91**	**0.397**	**0.338**	**13**	**0.176**	**0.175**	**7**
2000-2018	**0.261**	**0.218**	**106**	**0.272**	**0.270**	**29**	**0.252**	**0.230**	**30**	**0.250**	**0.190**	**30**

In general, TP concentrations in the Delaware River Watershed above Perry Lake are higher during high flow conditions (0-25%; **Figure 13**). For example, the Delaware River (SC554) has mean and median TP concentrations of 0.591 and 0.381 mg/L, respectively, during high flow conditions (**Table 7**). These concentrations are much lower during low flow conditions (76-100%), declining to a mean and median of 0.167 and 0.154 mg/L, respectively. Grasshopper Creek (SC603), Elk Creek (SC604), and Straight Creek (SC686) all exhibit a similar pattern as the Delaware River (SC554). All four stations have their highest mean and median TP concentrations during higher flow conditions. Higher TP concentrations during high flow conditions, displayed at these stations, are indicative of nonpoint source runoff influencing TP concentrations during precipitation events.

Figure 13. Total phosphorus by flow condition for Delaware River near Half Mound (SC554) Grasshopper Creek near Muscotah (SC603), Elk Creek near Larkinburg (SC604), and Straight Creek near Larkinburg (SC686).

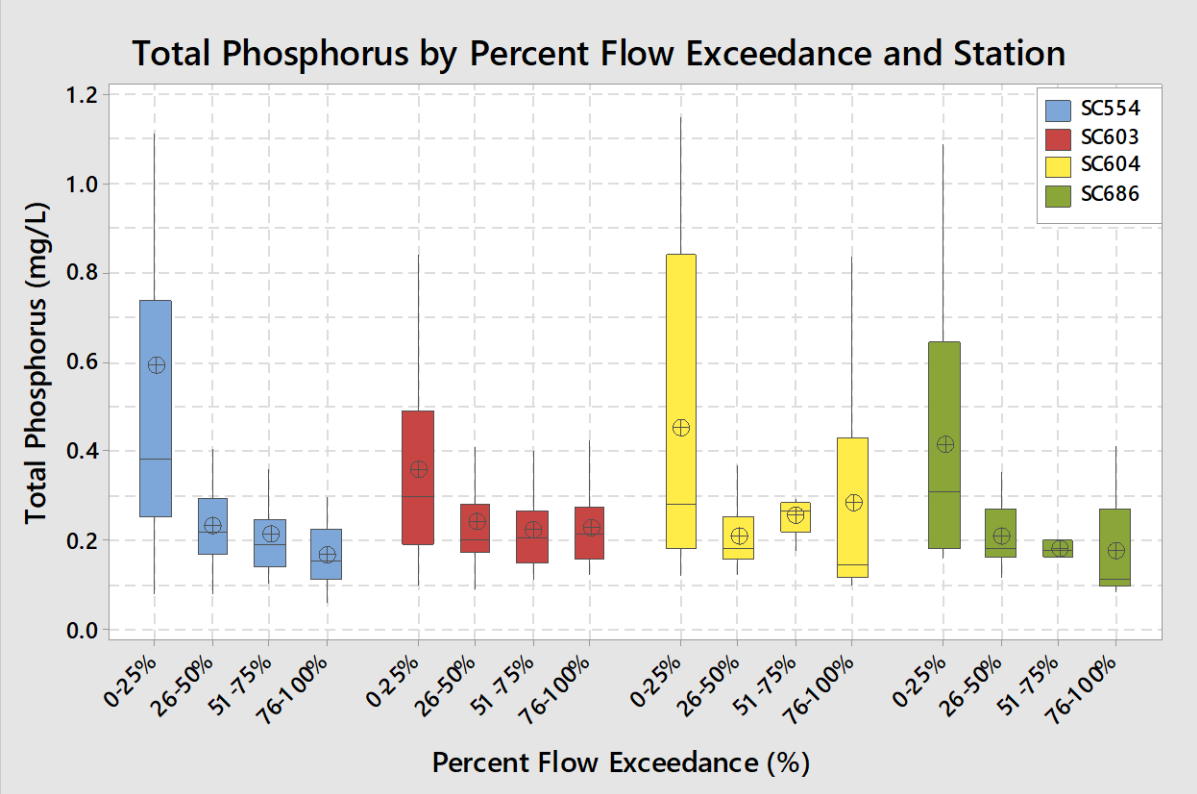


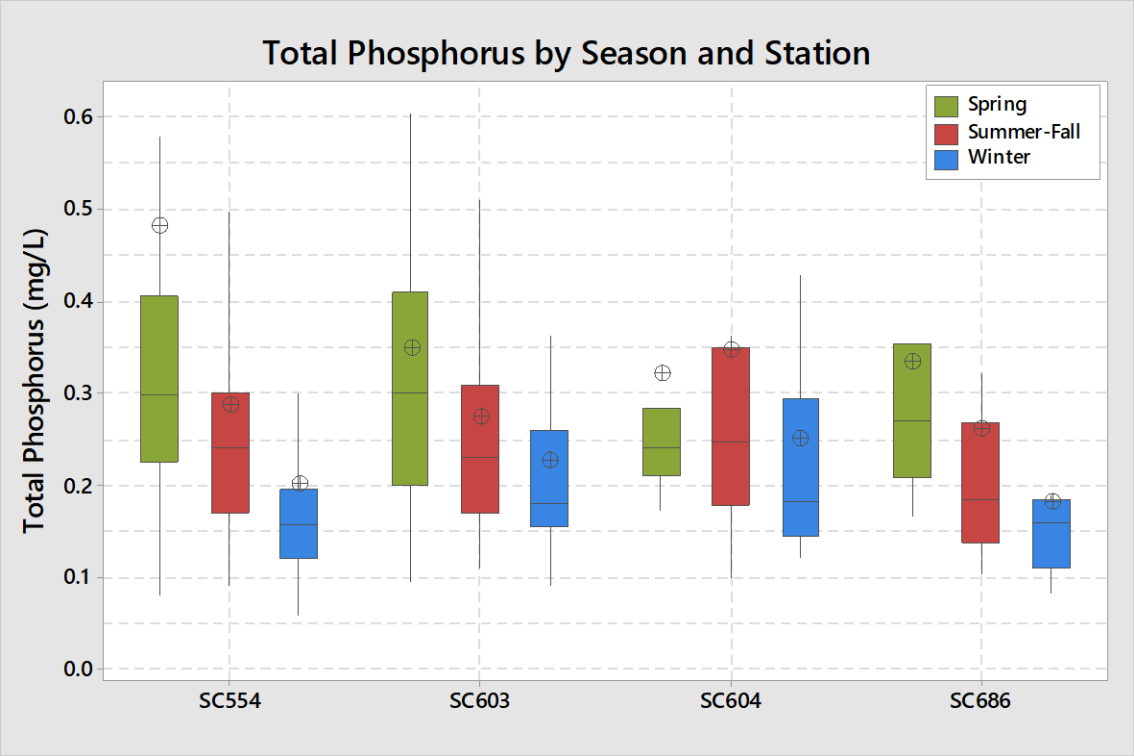
Table 7. Total phosphorus concentration mean, median, and number of samples (N) by season (spring: April through June, summer-fall: July through October, winter: November through March), flow range, and station in the Delaware River Watershed above Perry Lake.

Flow Exceedance (%)	Spring			Summer-Fall			Winter			All		
	Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N
Delaware River (SC554)												
0-25	0.685	0.380	24	0.603	0.459	12	0.392	0.277	12	0.591	0.381	48
26-50	0.267	0.266	16	0.267	0.260	5	0.178	0.170	13	0.233	0.221	34
51-75	0.325	0.245	8	0.223	0.207	21	0.156	0.140	21	0.211	0.191	50
76-100	0.260	0.260	1	0.187	0.179	24	0.129	0.121	15	0.167	0.154	40
0-100	**0.481**	**0.299**	**49**	**0.286**	**0.241**	**62**	**0.200**	**0.157**	**61**	**0.311**	**0.215**	**172**
Grasshopper Creek (SC603)												
0-25	0.394	0.331	16	0.441	0.383	10	0.279	0.210	17	0.359	0.300	43
26-50	0.310	0.280	12	0.243	0.230	5	0.171	0.175	13	0.238	0.201	30
51-75	0.225	0.225	2	0.241	0.220	19	0.181	0.160	9	0.222	0.205	30
76-100	0.320	0.320	1	0.200	0.198	12	0.279	0.275	4	0.226	0.215	17
0-100	**0.348**	**0.300**	**31**	**0.274**	**0.230**	**46**	**0.226**	**0.181**	**43**	**0.276**	**0.217**	**120**
Elk Creek (SC604)												
0-25	0.402	0.240	4	0.679	0.610	5	0.138	0.122	3	0.452	0.277	12
26-50	0.223	0.216	3	0.213	0.213	2	0.204	0.174	9	0.210	0.182	14
51-75	0.285	0.285	1	0.233	0.240	6	0.284	0.281	3	0.253	0.268	10
76-100	-	-	-	0.110	0.114	3	0.414	0.338	4	0.284	0.144	7
0-100	**0.320**	**0.240**	**8**	**0.347**	**0.247**	**16**	**0.250**	**0.182**	**19**	**0.299**	**0.240**	**43**
Straight Creek (SC686)												
0-25	0.423	0.310	3	0.705	0.705	2	0.212	0.170	3	0.414	0.308	8
26-50	0.298	0.270	3	0.215	0.186	3	0.162	0.168	6	0.210	0.184	12
51-75	0.166	0.166	1	0.199	0.197	5	0.132	0.132	2	0.178	0.177	8
76-100	-	-	-	0.110	0.110	3	0.305	0.126	6	0.172	0.110	9
0-100	**0.333**	**0.270**	**7**	**0.260**	**0.186**	**13**	**0.182**	**0.160**	**17**	**0.238**	**0.180**	**37**

Definition: – - no data

Seasonally, spring and summer-fall have greater TP means and medians than winter for all stations. (**Table 7; Figure 14**). The Delaware River (SC554), Grasshopper Creek (SC603), and Straight Creek (SC686) have TP concentrations that decline from spring to winter, while Elk Creek (SC604) has a slightly higher TP concentration in the summer-fall season than in the spring. This higher summer-fall concentration could be attributed to double the number of samples taken in the summer-fall than in the spring for this station. The seasons of spring and summer-fall typically have more precipitation and runoff events, which elevate TP concentrations due to nonpoint sources of TP loading.

Figure 14. Total phosphorus by season for Delaware River near Half Mound (SC554) Grasshopper Creek near Muscotah (SC603), Elk Creek near Larkinburg (SC604), and Straight Creek near Larkinburg (SC686).



Figures 15-18 display single sample TP concentrations by flow condition and season. In general, the influence of nonpoint sources can be seen in TP concentrations at all stations in the Delaware River Watershed above Perry Lake. Higher TP concentrations during higher flow and lower TP during lower flow conditions is indicative of nonpoint source loading to the watershed and can be seen in the Delaware River (SC554) and in Grasshopper Creek (SC603). Elk Creek (SC604) and Straight Creek (SC686) have smaller datasets and are not located on the stream segment where the USGS gage used to derive flows is located, therefore data points that plot up outside of the general pattern are likely the result of differing climate conditions in these subwatersheds (**Figure 17 and 18**).

Figure 15. Total phosphorus by percent flow exceedance and season for the Delaware River near Half Mound (SC554).

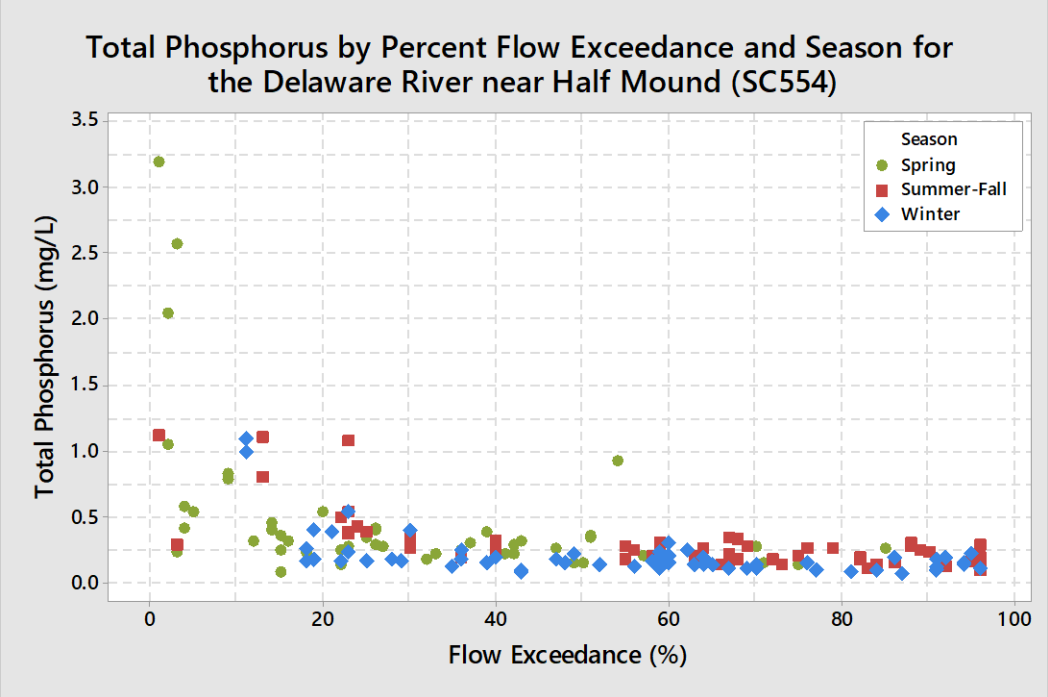


Figure 16. Total phosphorus by percent flow exceedance and season for Grasshopper Creek near Muscotah (SC603).

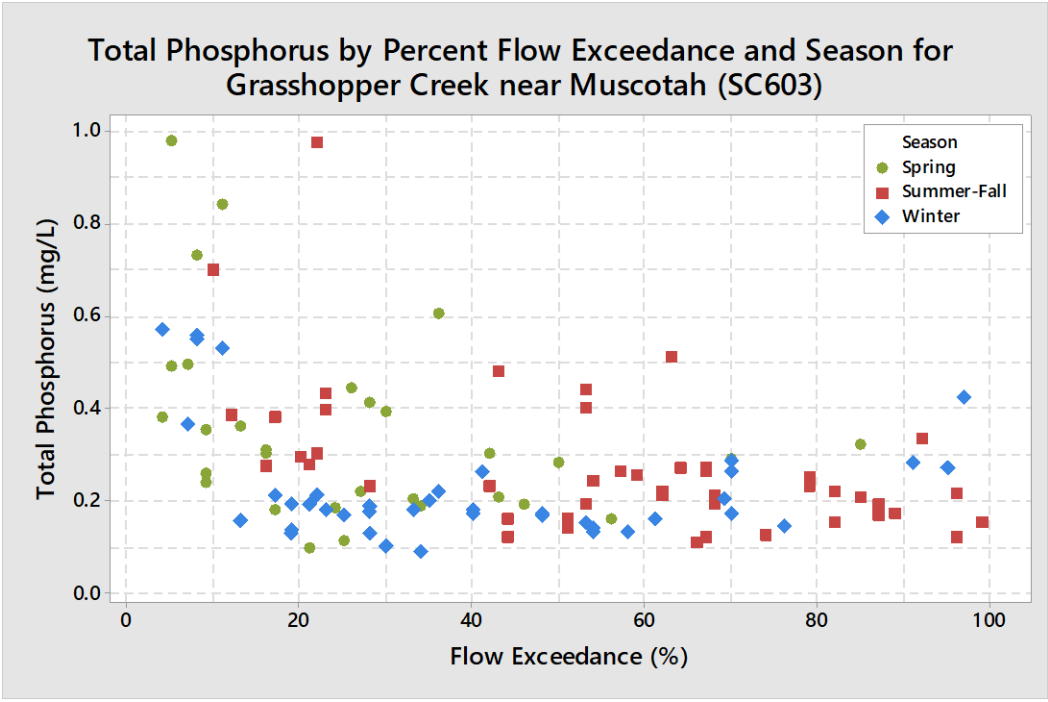


Figure 17. Total phosphorus by percent flow exceedance and season for Elk Creek near Larkinburg (SC604).

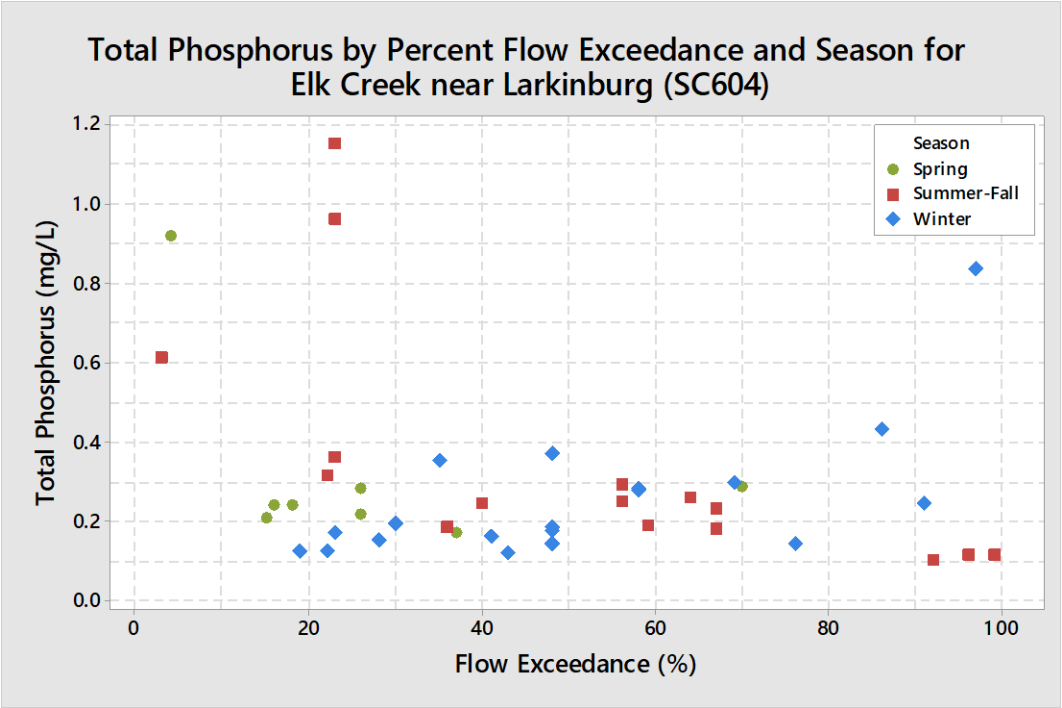
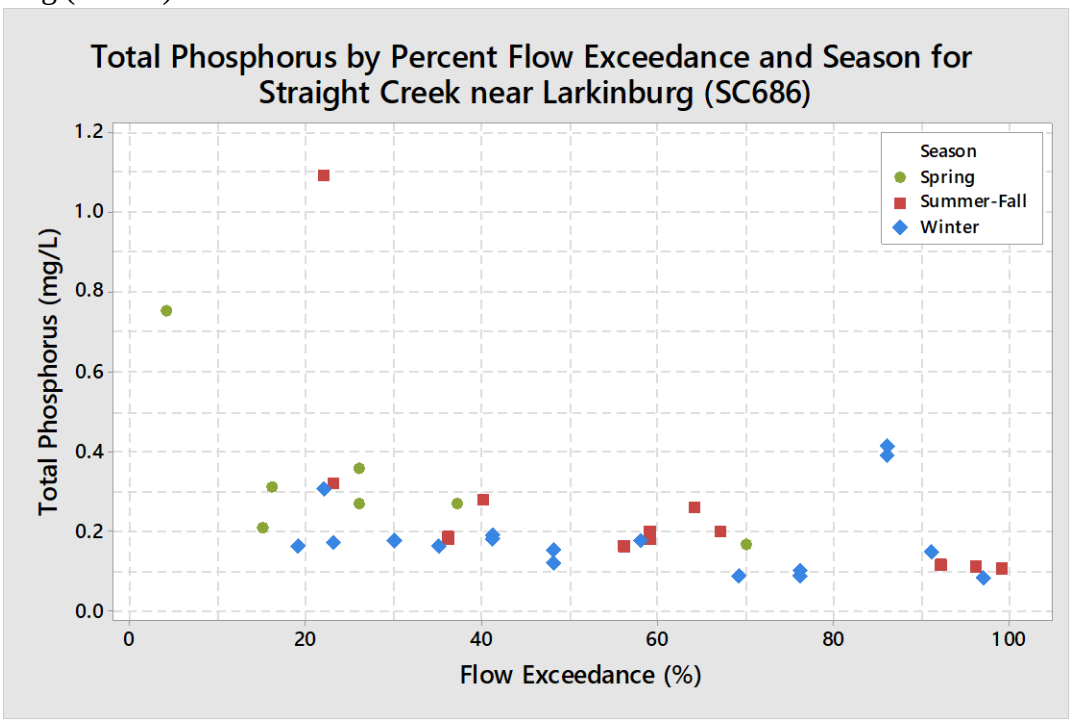


Figure 18. Total phosphorus by percent flow exceedance and season for Straight Creek near Larkinburg (SC686).



To further assess TP load sources for the Delaware River Watershed above Perry Lake, a mass balance was estimated based upon mean TP concentrations and streamflow for each watershed (Perry, 2004; **Table 8**). The total load is accumulative and reflects the total TP load at each station. The total load by watershed is incremental and reflects the total TP load contributed within each watershed. The mass balance calculation suggests that 43% of the load reaching the Delaware River near Half Mound (SC554) originates from the tributaries and main stem segments attached to that station. Of the remaining 57% of TP load, the remaining 3 stream chemistry stations on tributaries contribute 16, 18, and 23% of the watersheds load respectively.

Table 8. Estimated mass balance for total phosphorus loads based upon drainage area and mean streamflow (Perry, 2004) for the Delaware River above Perry Lake.

Station	Drainage Area (mi^2)	Mean Flow (cfs)	Mean Total Phosphorus (mg/L)	Total Phosphorus Load (lbs/day)	Total Phosphorus Load by Watershed (lbs/day)	Percent of Total Load (%)
Grasshopper Creek near Muscotah (SC603)	106	68.5	0.276	102.09	102.09	18
Elk Creek near Larkinburg (SC604)	134	83.6	0.299	134.98	134.98	23
Straight Creek near Larkinburg (SC686)	113	73.4	0.238	94.33	94.33	16
Delaware River near Half Mound (SC554)	761	347	0.311	582.75	251.35	43
Total	**761**	**347**	**0.311**	**582.75**	**582.75**	**100**

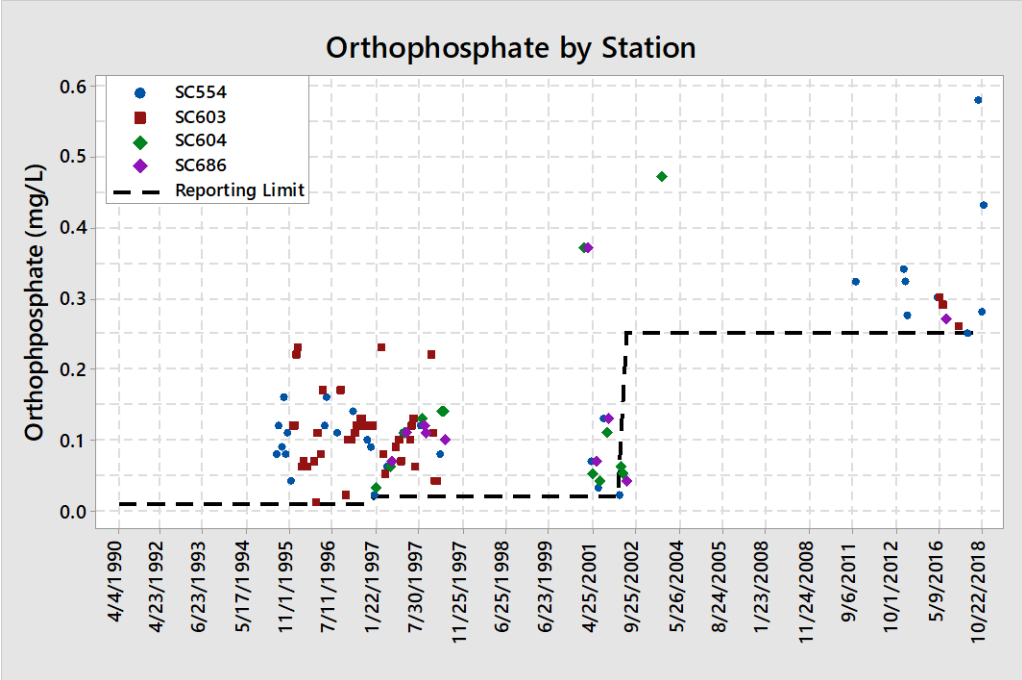
Total Phosphorus and Water Quality Parameters

Total phosphorus has well-established and defined relationships with orthophosphate (OP) and total suspended solids (TSS). These relationships are examined further to delineate potential sources of TP loading.

Orthophosphate

The soluble portion of TP that is readily available for biological use is OP. It is commonly found in higher concentrations in the discharge of municipal wastewater treatment plants (WWTPs) and can therefore be indicative of point source contributions of phosphorus in streams as well as an indication of runoff from livestock operations, instream livestock watering, and failing septic systems in the watershed. Only samples measuring above the reporting limit are included in the analysis presented which likely overestimates true OP concentration means. Reporting limits for OP have changed throughout the period of record: 0.01 mg/L from 1995-1996, 0.02 mg/L from 1997 to February 2002, and 0.25 mg/L from March 2002 to 2014. The Delaware River (SC554) has a total of 31 OP concentrations greater than the reporting limit, Grasshopper Creek (SC603) has a total of 41, Elk Creek (SC604) has a total of 13, and Straight Creek (SC686) has a total of 10. Overall, 25% of all samples had OP concentrations greater than the reporting limit. (**Figure 19**).

Figure 19. Orthophosphate samples measuring greater than the reporting limit Delaware River near Half Mound (SC554) Grasshopper Creek near Muscotah (SC603), Elk Creek near Larkinburg (SC604), and Straight Creek near Larkinburg (SC686).



Total Suspended Solids

There is a strong relationship between TP and TSS concentrations when point source contributions are minimized and nonpoint source loading dominates. Phosphorus is typically linked to sediment or TSS because of the propensity of those solids to adsorb phosphorus. **Figure 20-23** display the relationship between TP and TSS. In the Delaware River (SC554), Grasshopper Creek (SC603), and Straight Creek (SC686) TSS levels show a positively correlated relationship between TP and TSS. Elk Creek (SC604) displays a positively correlated relationship, where concentrations above 0.5 mg/L weaken the relationship. These positive correlations indicate that point sources are not influencing the TP concentrations at these stations.

Figure 20. Total phosphorus versus total suspended solids for the Delaware River near Half Mound (SC554).

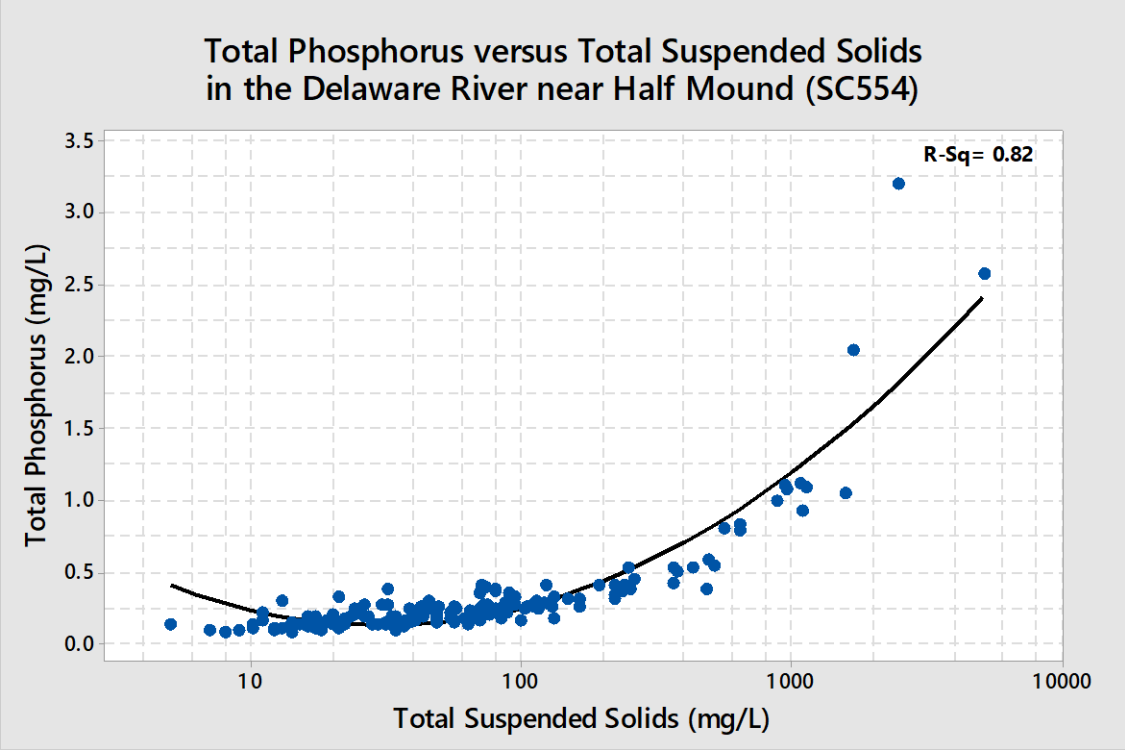


Figure 21. Total phosphorus versus total suspended solids for Grasshopper Creek near Muscotah (SC603).

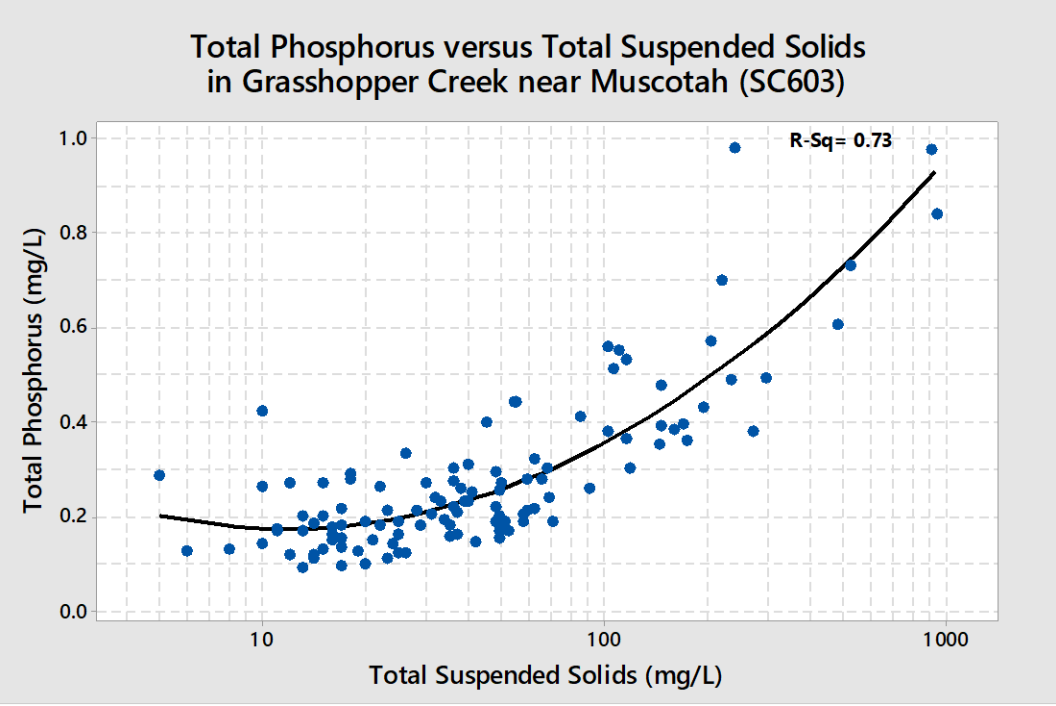


Figure 22. Total phosphorus versus total suspended solids for Elk Creek near Larkinburg (SC604).

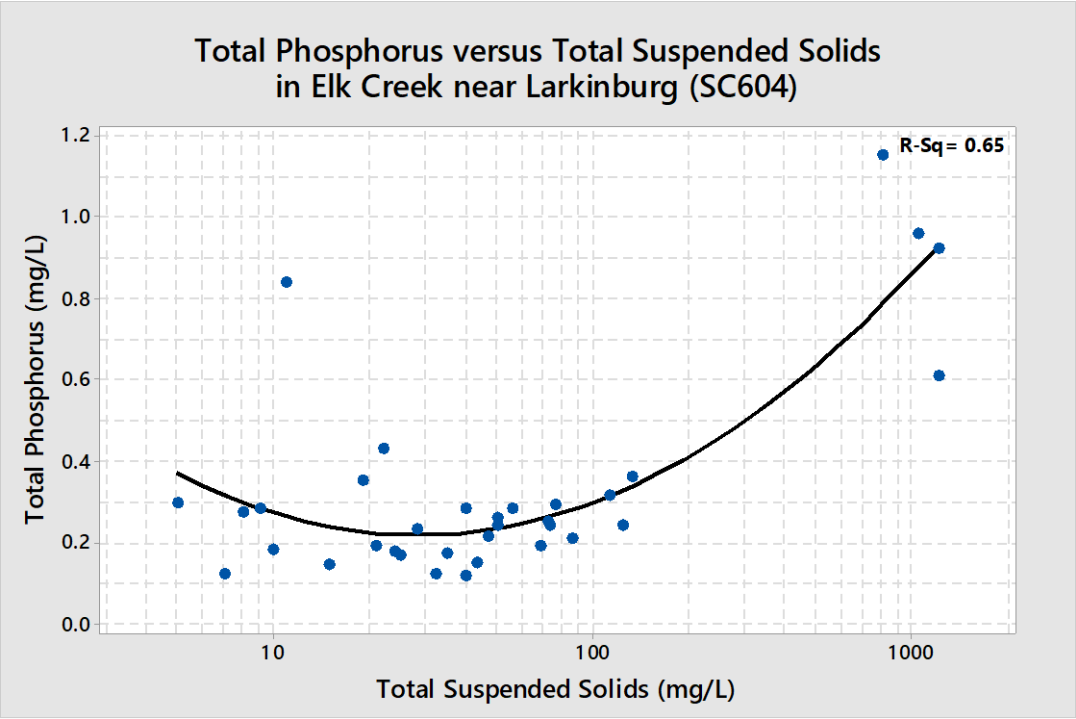
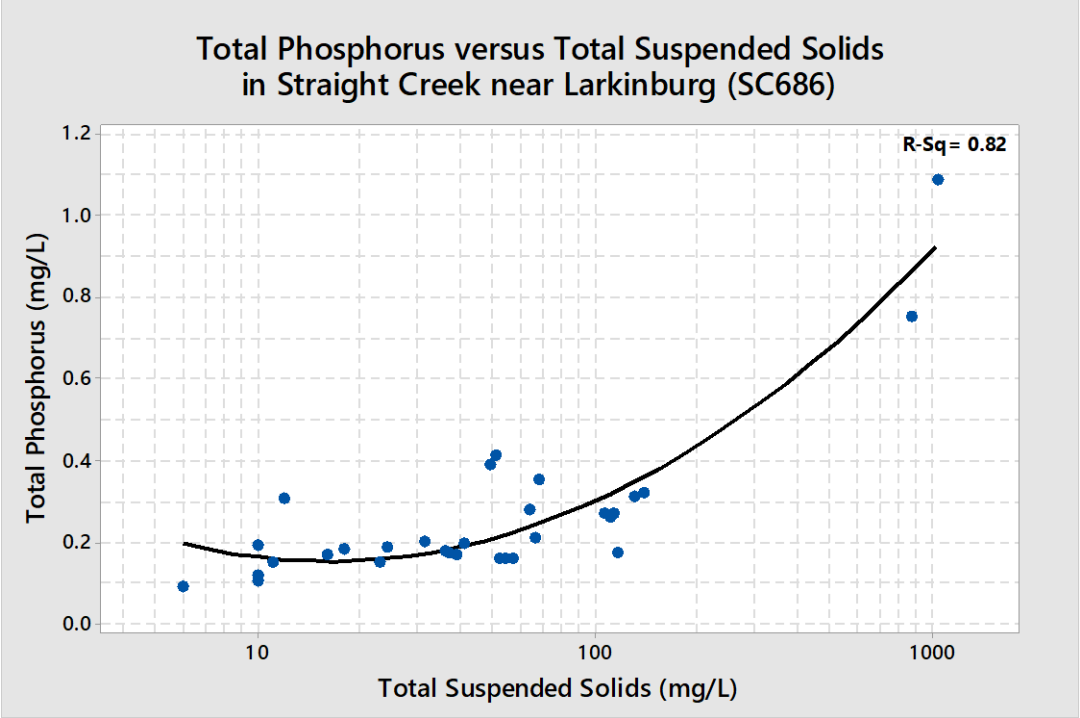


Figure 23. Total phosphorus versus total suspended solids for Straight Creek near Larkinburg (SC686).



Total Phosphorus and Biological Indicators

The narrative criteria of the Kansas Surface Water Quality Standards are based on conditions of the prevailing biological community. Excessive primary productivity may be indicated by extreme shifts in dissolved oxygen (DO), dissolved oxygen saturation (DO saturation), and pH as the chemical reactions of photosynthesis and respiration alter the ambient levels of oxygen and acid-base balance of the stream. These extreme shifts, in turn, can result in undesirable regime shifts in the algal biomass and biological community within the stream.

Dissolved Oxygen

In the Delaware River Watershed above Perry Lake no samples tested below the water quality criterion of 5 mg/L (**Figures 24-27**). Dissolved oxygen and temperature are inversely related for the Delaware River (SC554), Grasshopper Creek (SC603), Elk Creek (SC604), and Straight Creek (SC686). This relationship is stronger in the Delaware River (SC554) and in Grasshopper Creek (SC603). The relationship between DO and Temperature corresponds to seasonal changes and is expected because oxygen becomes less soluble in water as temperatures increase (**Table 9**). Additionally, DO exhibits a diel trend due to daily fluctuations in photosynthetic activity. The presented data captures this daily variability based upon whether a sample was collected in the morning (8:00 am to 12:00 pm) or afternoon (12:00 to 19:00 pm); morning samples tend to have lower DO concentrations and afternoon samples tend to have higher DO concentrations. **Figures 24 and 25** clearly display this pattern in the Delaware River (SC554) and in Grasshopper Creek (SC603).

Figure 24. Dissolved oxygen by date and dissolved oxygen versus temperature for the Delaware River near Half Mound (SC554).

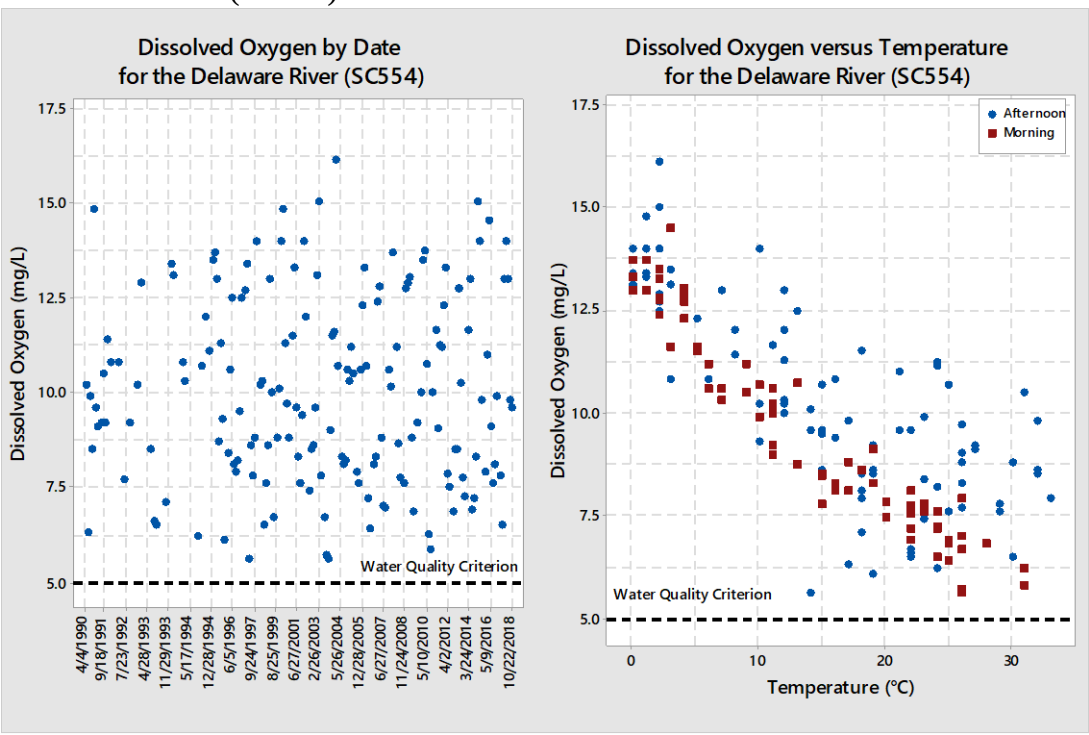


Figure 25. Dissolved oxygen by date and dissolved oxygen versus temperature for Grasshopper Creek near Muscotah (SC603).

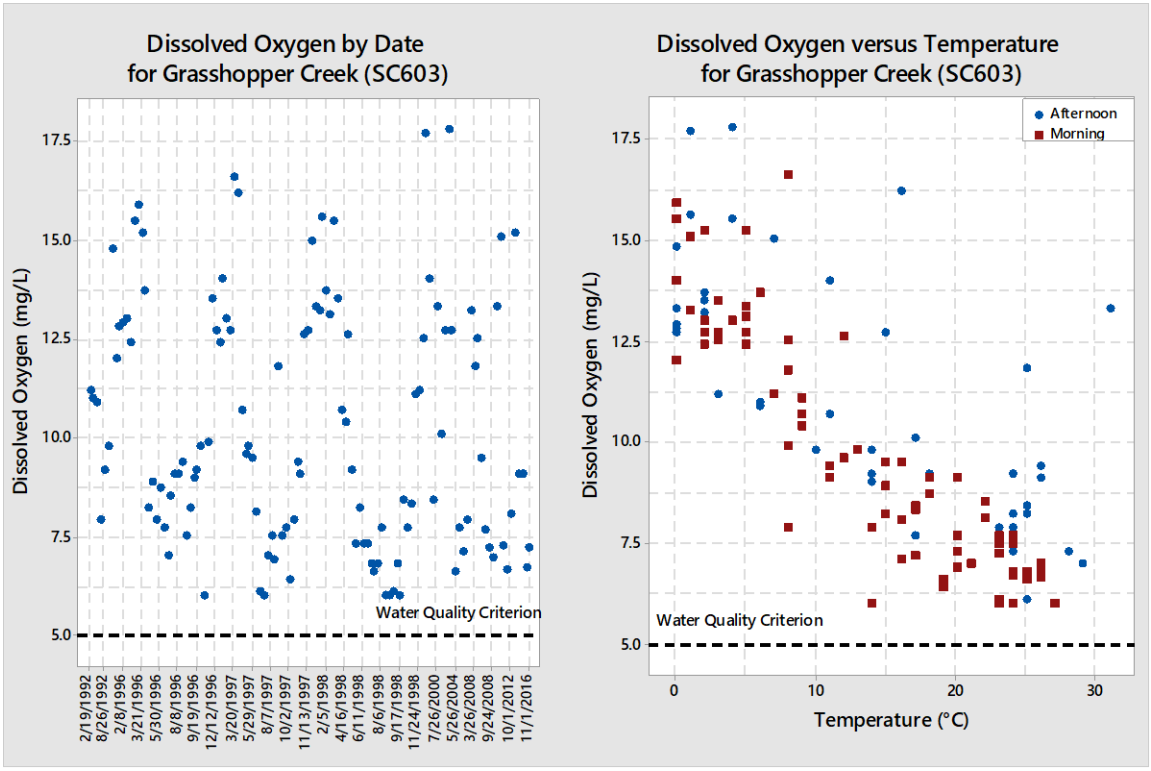


Figure 26. Dissolved oxygen by date and dissolved oxygen versus temperature for Elk Creek near Larkinburg (SC604).

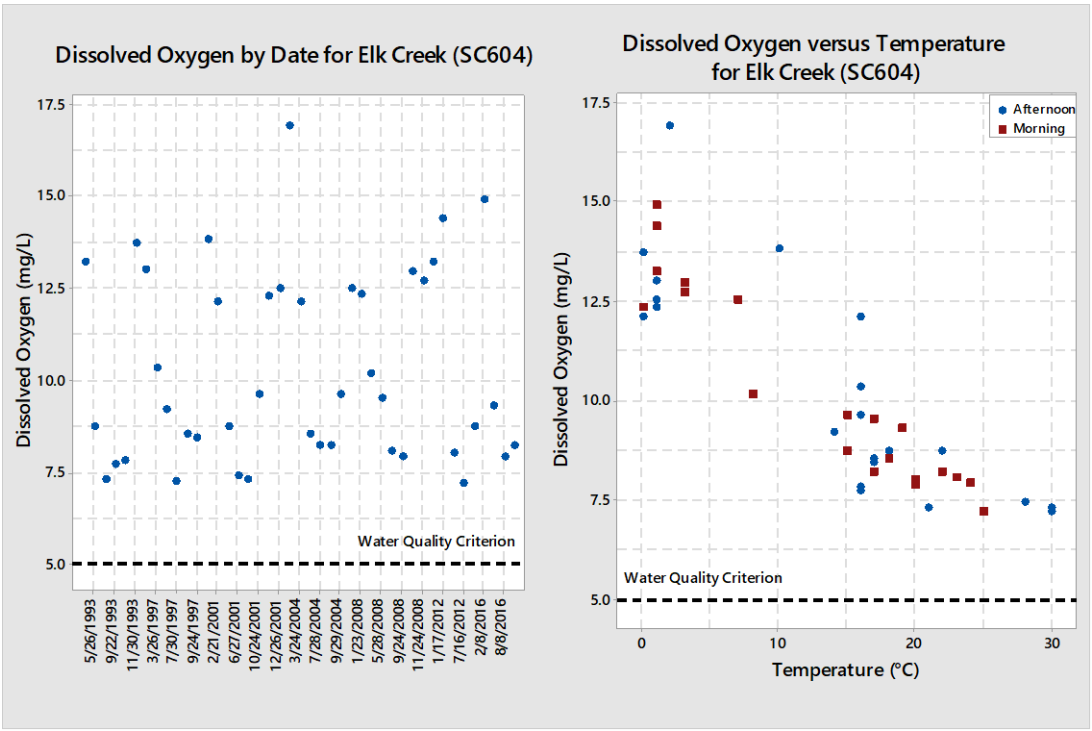


Figure 27. Dissolved oxygen by date and dissolved oxygen versus temperature for Straight Creek near Larkinburg (SC686).

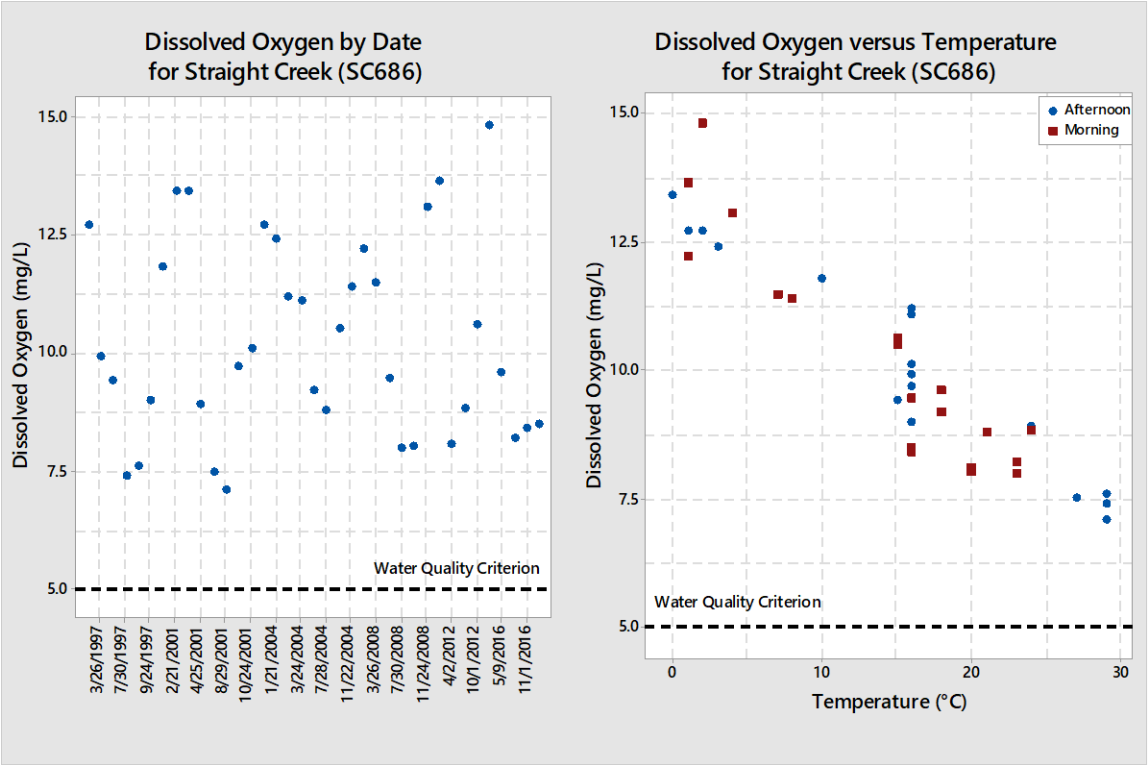


Table 9. Mean temperature, dissolved oxygen, and dissolved oxygen saturation, as well as median pH, by season for the Delaware River Watershed above Perry Lake.

Station	Spring	Summer-Fall	Winter	All Seasons
Temperature (°C)				
Delaware River (SC554)	19.2	21.1	4.9	14.9
Grasshopper Creek (SC603)	17.4	20.7	3.9	13.8
Elk Creek (SC604)	19.5	20.5	4.7	13.4
Straight Creek (SC686)	19.7	21.2	7.0	14.4
Dissolved Oxygen (mg/L)				
Delaware River (SC554)	8.8	8.6	12.3	10.0
Grasshopper Creek (SC603)	9.2	8.0	13.4	10.2
Elk Creek (SC604)	8.7	8.1	12.7	10.2
Straight Creek (SC686)	8.9	8.8	11.9	10.2
Dissolved Oxygen Saturation (%)				
Delaware River (SC554)	91.7	95.3	94.7	94.1
Grasshopper Creek (SC603)	94.0	88.5	101.2	94.5
Elk Creek (SC604)	93.9	89.5	97.6	93.9
Straight Creek (SC686)	96.5	97.5	96.3	96.8
pH				
Delaware River (SC554)	7.9	7.9	7.9	7.9
Grasshopper Creek (SC603)	8.0	8.0	8.0	8.0
Elk Creek (SC604)	8.0	7.9	8.0	8.0

Station	Spring	Summer-Fall	Winter	All Seasons
Straight Creek (SC686)	8.0	8.0	7.9	7.9

Dissolved Oxygen Saturation

Primary productivity increases in the spring and summer-fall, when temperatures are higher and DO concentrations are lower. When primary productivity is excessive, oxygen from aquatic photosynthesis can create DO concentrations that exceed the natural oxygen equilibrium of the stream at a given temperature. Supersaturated conditions occur when the ratio of the oxygen capacity of the stream at a given temperature to the oxygen concentration in the stream exceeds 110%. Because of the system's diel characteristics, supersaturated conditions are more likely to be detected in the afternoon when photosynthesis and temperatures are at their peak. Delaware River (SC554) and Grasshopper Creek (SC603) strongly display this pattern. Throughout the period of record, Delaware River (SC554) has 21 DO saturation values greater than 110% (**Figure 28**). Grasshopper Creek (SC603) has 16 DO saturation values greater than 110% (**Figure 29**). Elk Creek (SC604) has 3 DO saturation values greater than 110% (**Figure 30).** Straight Creek (SC686) has 2 DO saturation values greater than 110% (**Figure 31).**

Figure 28. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature for the Delaware River near Half Mound (SC554).

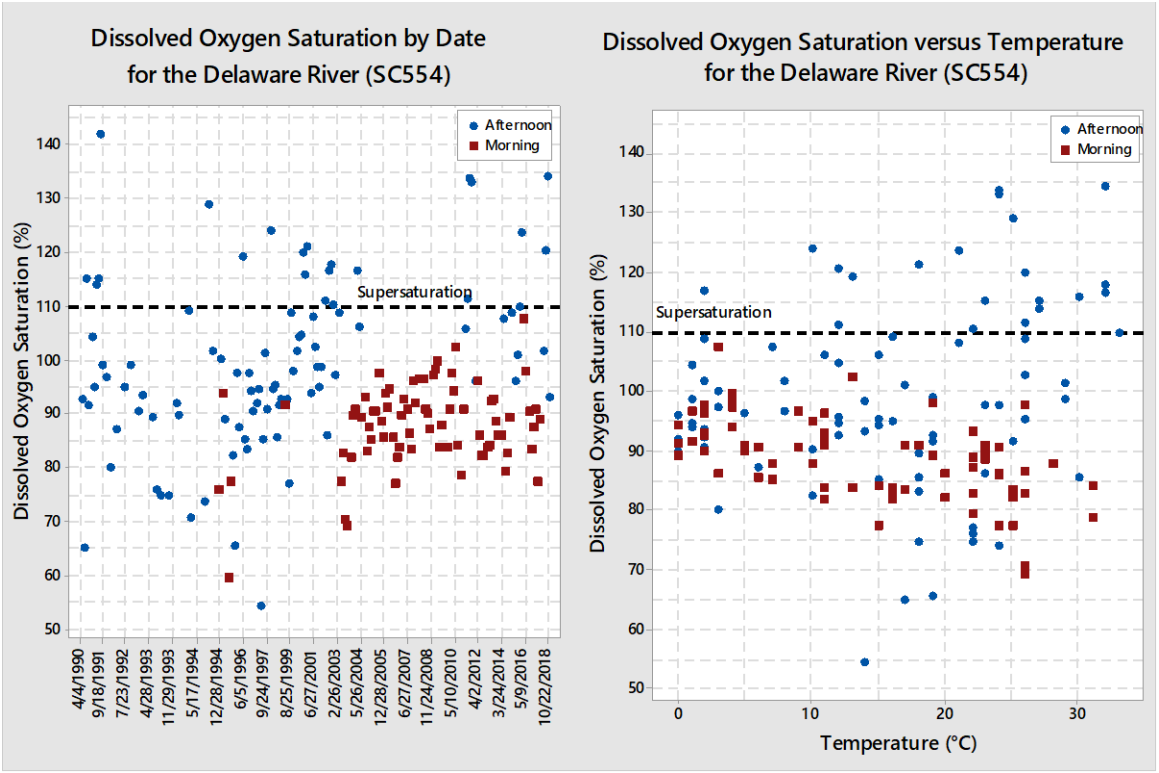


Figure 29. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature for Grasshopper Creek near Muscotah (SC603).

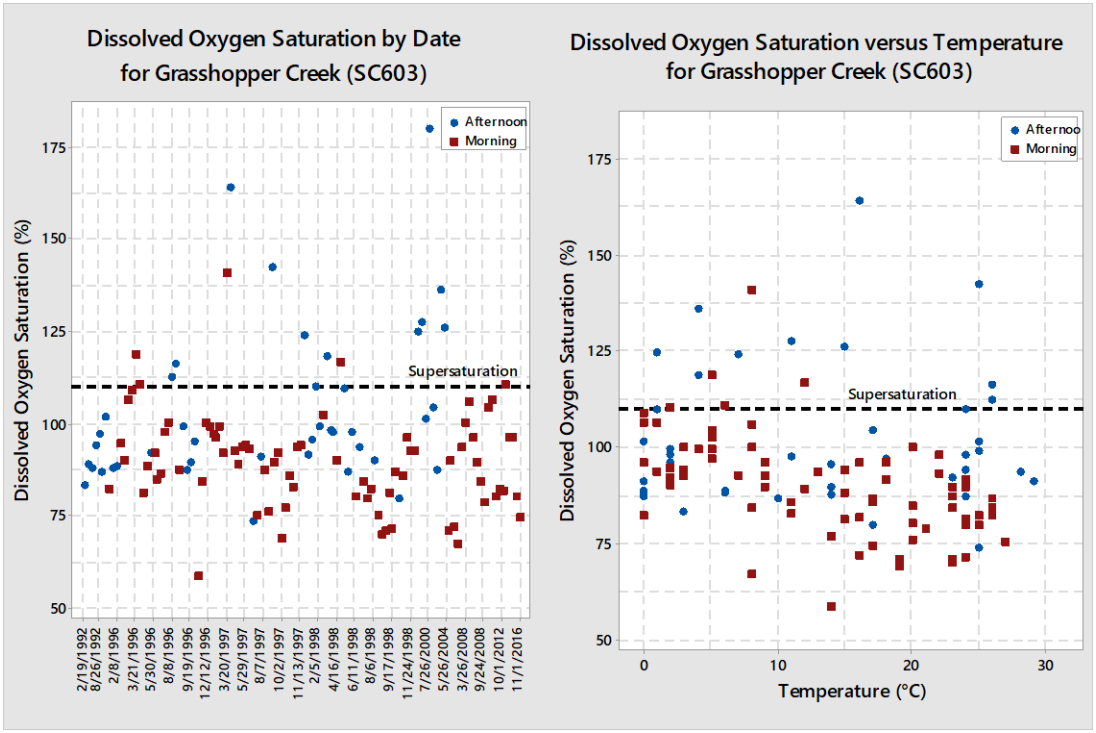


Figure 30. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature for Elk Creek near Larkinburg (SC604).

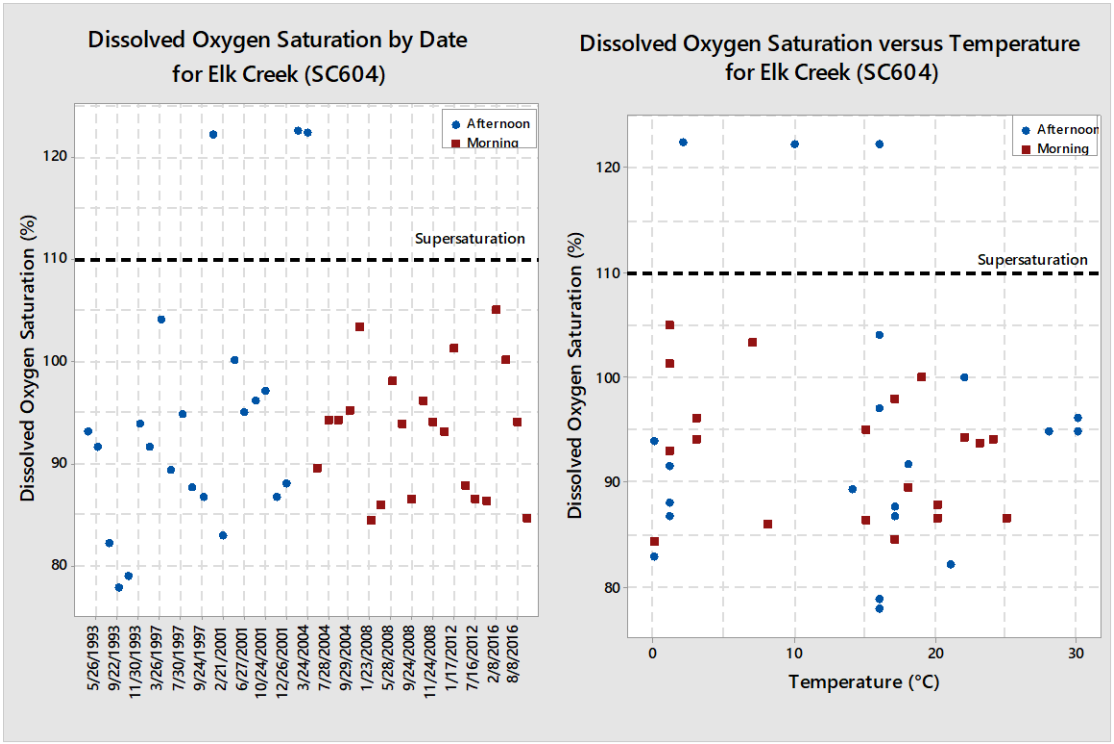
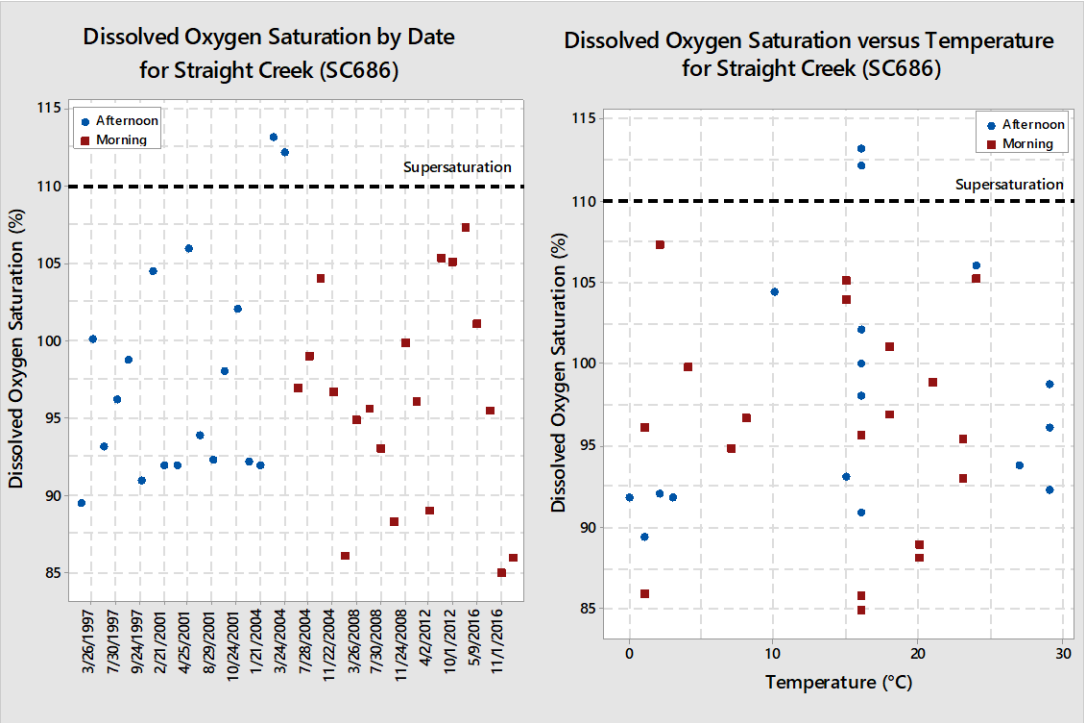


Figure 31. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature for Straight Creek near Larkinburg (SC686).



pH

Another water quality indicator of primary productivity is pH, as photosynthesis can increase pH via consumption of carbon dioxide in the water. The numeric water quality criteria for pH is a range from 6.5 to 8.5. There are no pH excursions for the Delaware River (SC554; **Figure 32**). There are two pH excursions for Grasshopper Creek (SC603) that occurred in March and July 2000 (**Figure 33**). There are no pH excursions for the Elk Creek (SC604) or Straight Creek (SC686) (**Figures 34-35**).

Figure 32. The pH and the relationship between pH and temperature for the Delaware River near Half Mound (SC554).

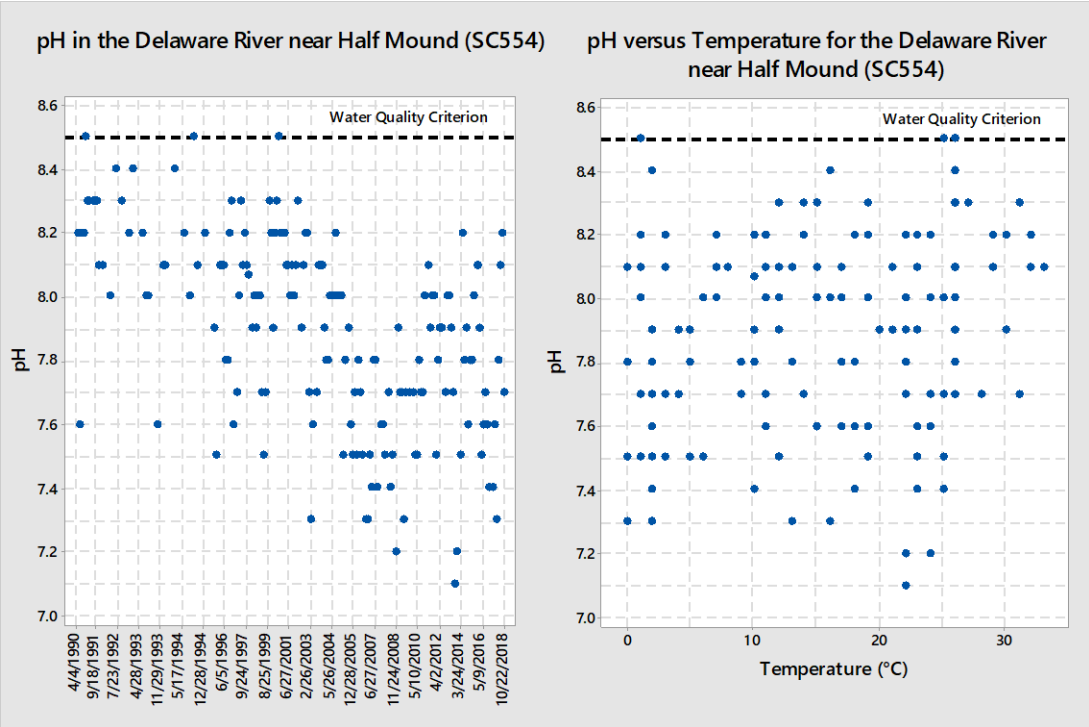


Figure 33. The pH and the relationship between pH and temperature for Grasshopper Creek near Muscotah (SC603).

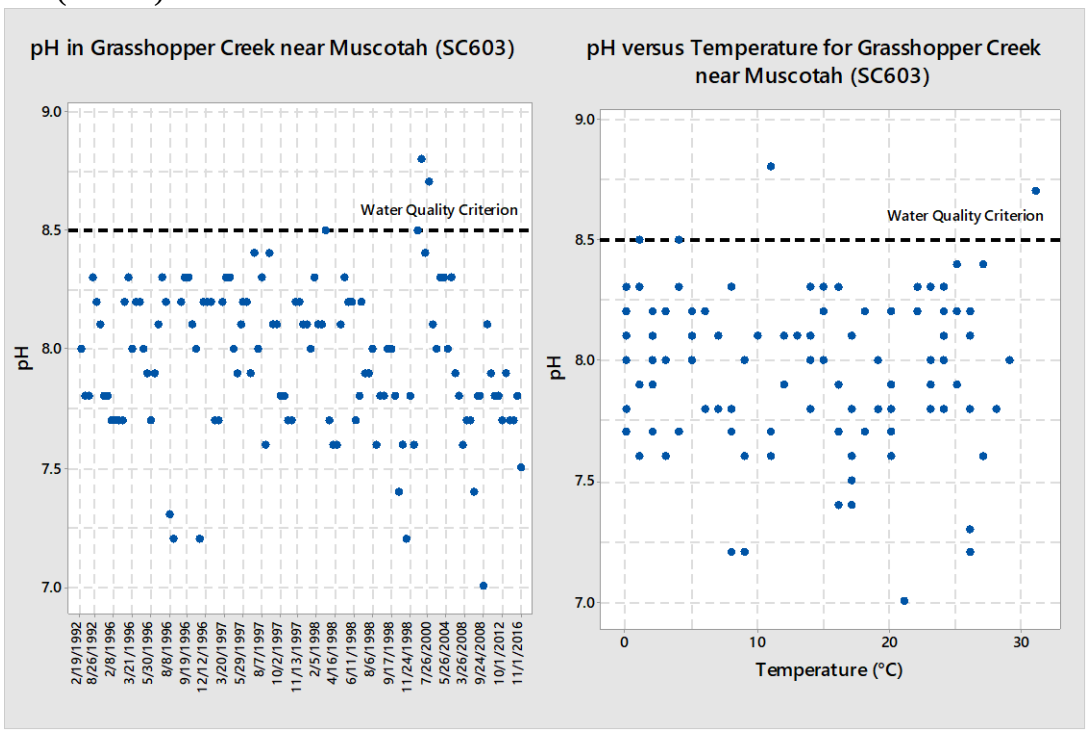


Figure 34. The pH and the relationship between pH and temperature for Elk Creek near Larkinburg (SC604).

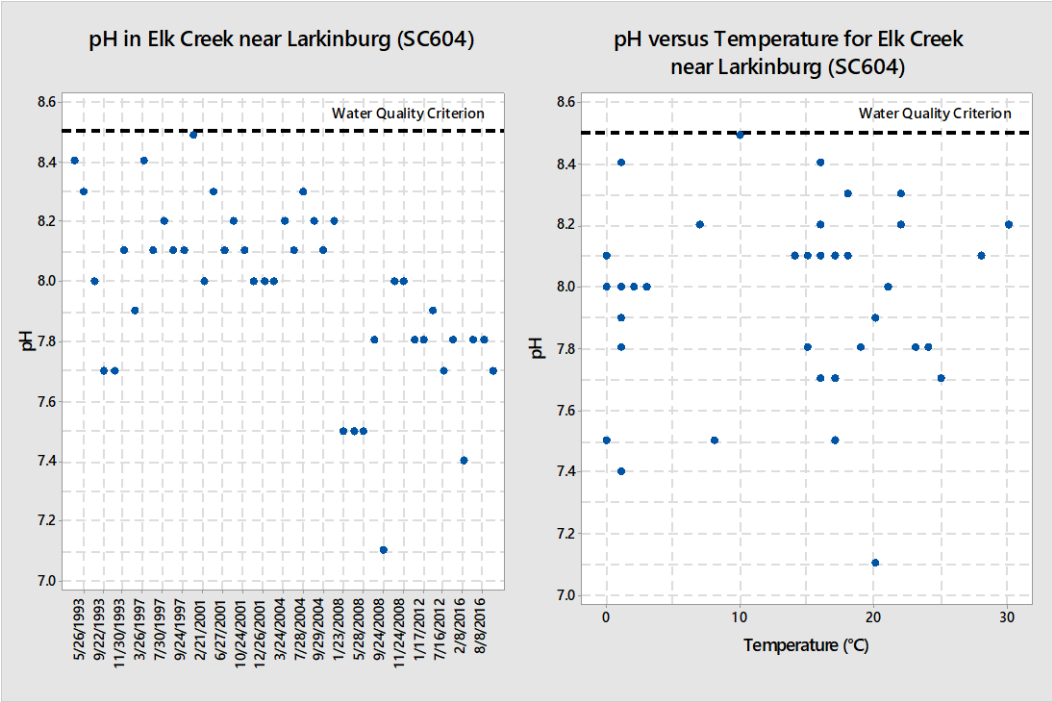
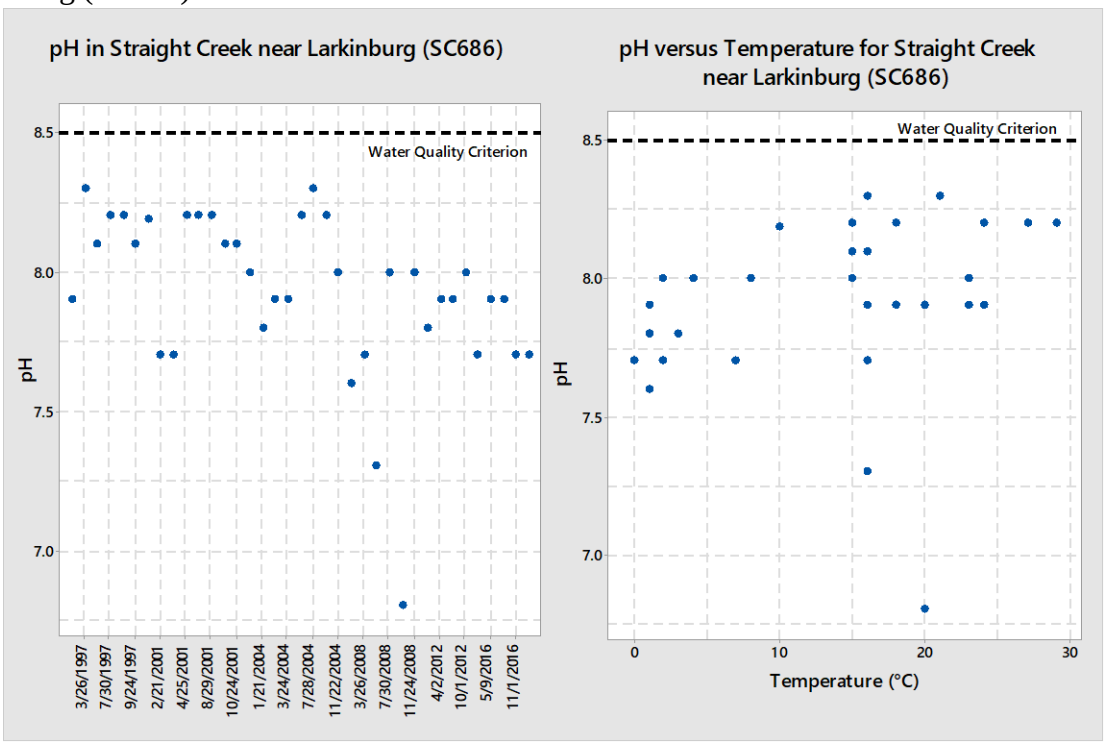


Figure 35. The pH and the relationship between pH and temperature for Straight Creek near Larkinburg (SC686).



Data regarding macroinvertebrate organisms and community are collected at KDHE stream biology (SB) stations SB352, SB360, SB407 and SB408, located in the Delaware River Watershed above Perry Lake. KDHE's Stream Biological Monitoring Program uses the Aquatic Life Use Support Index (ALUS Index) to assess stream biology as described in Kansas' 2018 303(d) Methodology. The ALUS Index consists of five categorizations of biotic condition that, once measured, are assigned a score (**Table 10**). Scores are then tallied, and a support category is assigned according to **Table 11.**

1. Macroinvertebrate Biotic Index (MBI): A statistical measure that evaluates the effects of nutrients and oxygen demanding substances on macroinvertebrates based on the relative abundance of certain indicator taxa (orders and families).
2. Ephemeroptera, Plecoptera, and Trichoptera (EPT) abundance as a percentage of the total abundance of macroinvertebrates.
3. Kansas Biotic Index for Nutrients (KBI-N): Mathematically equivalent to the MBI, however, the tolerance values are species specific and restricted to aquatic insect orders.
4. EPT Percent of Count (EPT % CNT): The percentage of organisms in a sample consisting of individuals belonging to the EPT orders.
5. Shannon's Evenness (SHN EVN): A measure of diversity that describes how evenly distributed the numbers of individuals are among the taxa in a sample.

Table 10. ALUS Index metrics with scoring ranges.

MBI	KBI-N	EPT	EPT % CNT	SHN EVN	Score
<= 4.18	<= 2.52	>= 16	>= 65	>= 0.849	4
4.19-4.38	2.53-2.64	14-15	56-64	0.826-0.848	3
4.39-4.57	2.65-2.75	12-13	48-55	0.802-0.825	2
4.58-4.88	2.76-2.87	10-11	38-47	0.767-0.801	1
>= 4.89	>= 2.88	< = 9	<= 37	<= 0.766	0

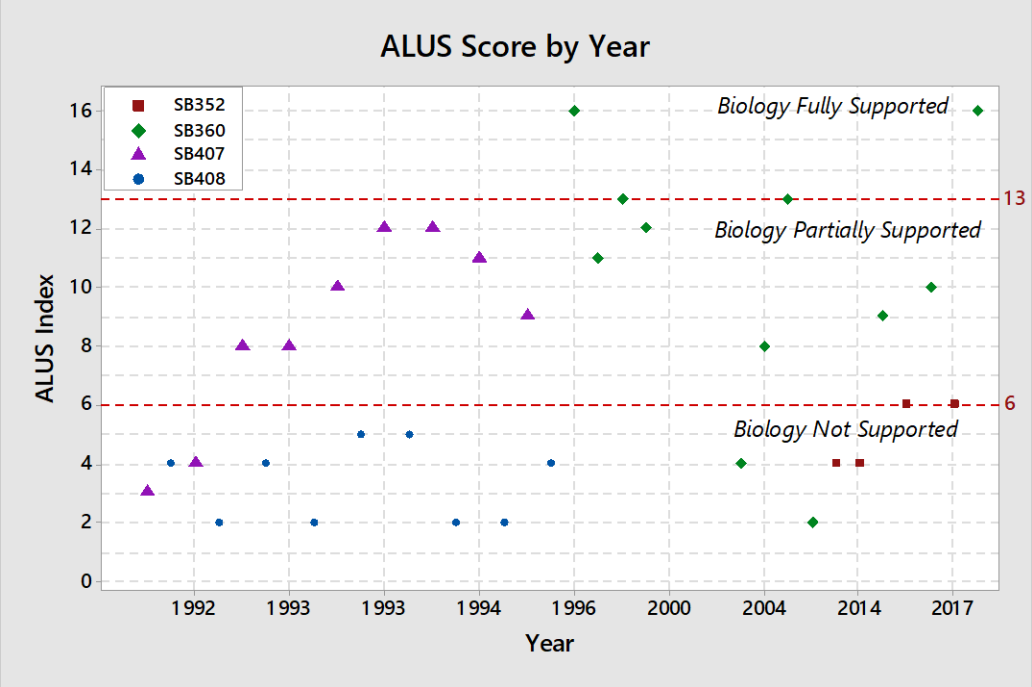
Table 11. ALUS Index score range, interpretation of biotic condition, and supporting, partial, and non-supporting categories.

ALUS Index Score	Biotic Condition	Support Category
>16 - 20	Very Good	Supporting
>13 - 16	Good	
>7 - 13	Fair	Partially Supporting
>3 - 6	Poor	Non-Supporting
0 - 3	Very Poor	

Biotic conditions were sampled in the Delaware River near the headwater but below the river's confluence with Cedar Creek (SB352) from 2013 to 2016, and downstream in the Delaware River (SB360) from 1996 to 2016 in the Delaware River, Muddy Creek (SB407) from 1992 to 1994, and Delaware River (SB408) from 1992 to 1994. The Delaware River (SB352) station has a total of 4 samples with a mean ALUS Index Score of 5, indicating biotic conditions are poor and not supportive of aquatic life. The Delaware River (SB360) station has a total of 11 samples with a mean ALUS Index Score of 10, indicating biotic conditions are fair and partially supportive of aquatic life. The Muddy Creek (SB407) station has a total of 9 samples with a

mean ALUS Index Score of 9, indicating biotic conditions are fair and partially supportive of aquatic life. The Delaware River (SB408) station has a total of 9 samples with a mean ALUS Index Score of 3, indicating biotic conditions are poor and not supportive of aquatic life (**Figure 36**).

Figure 36. Aquatic Life Use Support Index scores in the Delaware River watershed, 1990 to 2017.



Desired Endpoint: The ultimate desired water quality endpoints of this TMDL will be to achieve the Kansas Water Quality Standards by eliminating the impacts to aquatic life, domestic water supply, and contact recreation associated with excessive phosphorus and objectionable flora as described in the narrative criteria pertaining to nutrients. There are currently no existing numeric phosphorus criteria in Kansas.

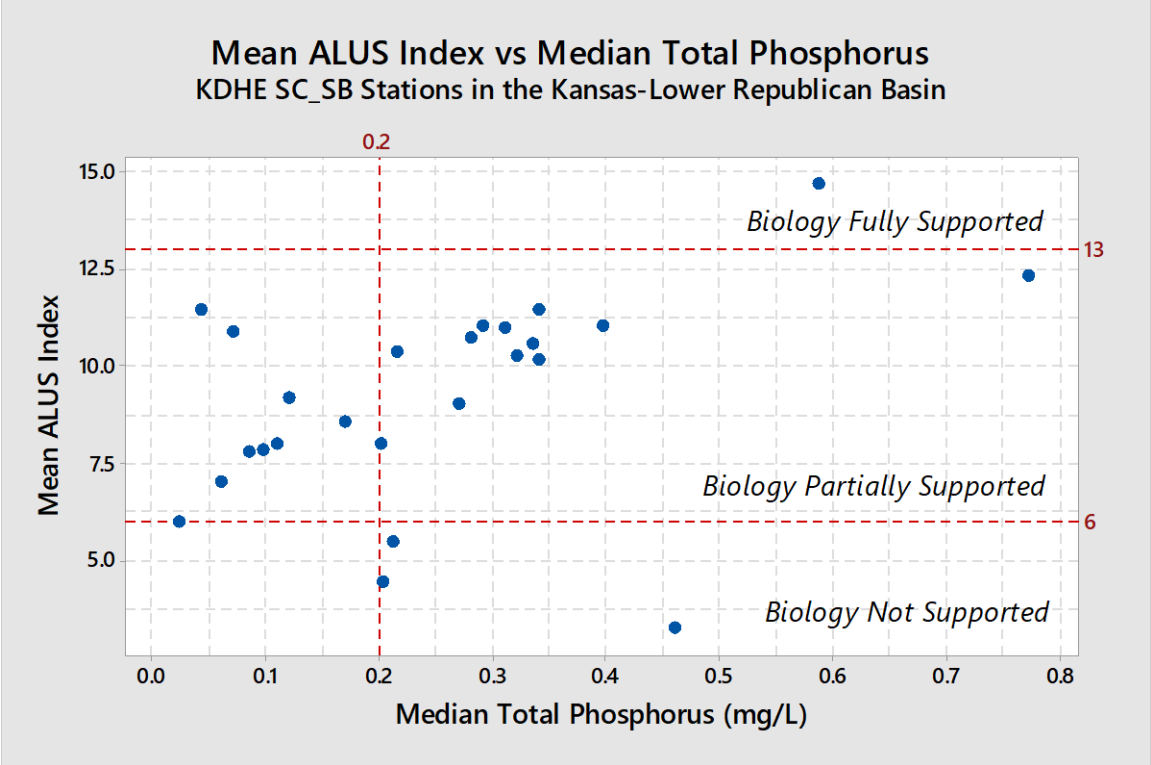
The Delaware River Watershed above Perry Lake lies within U.S. EPA Level IV Ecoregion of the Loess and Glacial Drift Hills (47i). Assessment of TP data from the 17 KDHE monitoring stations located in the Loess and Glacial Drift Hills ecoregion for the 2000 through 2018 period of record was used to establish TP milestones for the TMDL included in this document.

Table 12. TP summary data of ecoregion 47i stream chemistry stations located in Kansas for total phosphorus, 2000-2018.

USEPA Ecoregion	Number of KDHE Stations	Number of Samples	25th Percentile of Medians (mg/L)	50th Percentile of Medians (mg/L)	75th Percentile of Medians (mg/L)
Loess and Glacial Drift Hills	17	809	0.174	0.209	0.257

Figure 37 displays the relationship between median phosphorus values and ALUS Index scores within the Kansas-Lower Republican Basin. Higher ALUS Index scores are indicative of higher quality biological communities. There are 25 KDHE monitoring stations located in the Loess and Glacial Drift Hills (47i) Ecoregion that have corresponding biology and TP datasets over the 1990 through 2017 period of record.

Figure 37. Median total phosphorus (TP) versus mean Aquatic Life Use Score (ALUS) Index for stream chemistry/stream biology (SC/SB) stations located in Kansas-Lower Republican Basin from with TP and Biology from 1990-2017.



The greatest complication in setting an endpoint is establishing the linkage of phosphorus levels to applicable biologic response variables. Displayed in **Figure 37** is a noisy relationship between the ALUS Index and phosphorus that defies establishing a solitary threshold value and supports an adaptive management approach to reduce current phosphorus loads and concentrations; this adaptive management approach requires observing and responding to improvement in biological metrics and sestonic chlorophyll *a* prior to further reductions.

Therefore, the primary measure of reduction in nutrient loading to the impaired segments in the TMDL watershed will be the ALUS Index. The ALUS Index will serve to establish if the biological community at the SB stations in the watershed reflect recovered, renewed diversity and minimal disruption by the impacts described in the narrative criteria for nutrients on aquatic life, recreation, and domestic water supply.

Additionally, the concentration of floating sestonic phytoplankton in the water column at SC554, SC603, SC604 and SC686 as determined by measuring the sestonic chlorophyll *a* concentrations in the Delaware River Watershed above Perry Lake will indicate if primary productivity has moderated to reduce the impacts described in the narrative criteria for nutrients on aquatic life, recreation, and domestic water supply along the reaches of the Delaware River Watershed above Perry Lake.

Secondary indicators of the health of the in-stream biological community include:

1. Dissolved oxygen concentrations greater than 5.0 mg/L and the percent dissolved oxygen not more than 110%. Percent dissolved oxygen saturation is the measure of oxygen in the water relative to the water's potential dissolved oxygen concentration. Dissolved oxygen concentrations below 5.0 mg/L put aquatic life under stress while dissolved oxygen percent saturation levels greater than 110% are indicative of over-active primary productivity.
2. Instream pH values remain below 8.5. Excessive nutrients can induce vigorous photosynthesis which will cause pH to rise above 8.5, the current Kansas criterion.

Therefore, the numeric endpoints for this TMDL indicating attainment of water quality standards within the watershed are:

1. An ALUS Index score greater than 13 at SB stations.
2. Maintain median sestonic chlorophyll *a* concentration equal to or below 10 µg/L at SC stations.
3. Dissolved oxygen concentrations greater than 5.0 mg/L at SC stations.
4. Dissolved oxygen saturation below 110% at SC stations.
5. pH values within the range of 6.5 to 8.5 at SC stations.

All five endpoints have to be initially maintained over three consecutive years to constitute full support of the designated uses of the Delaware River Watershed and its tributaries. After the endpoints are attained, simultaneous digression of these endpoints more than once every three years on average constitutes a resumption of impaired conditions in the stream unless the TP impairment is delisted through the 303(d) process.

There are no existing numeric phosphorus criteria currently in Kansas. Hence, the series of endpoints established by this TMDL will be the measures used to indicate full support of the designated uses for the creek and river. These endpoints will be evaluated periodically as phosphorus levels decline in the watershed over time with achievement of the ALUS Index endpoint indicating restored status of the aquatic life use in the river.

This TMDL looks to establish phased total phosphorus endpoints that will be the cue to examine for altered, improved biological conditions in the creek and river. Assessment of the biological community in the watershed will be initiated once concentrations approach the Phase I management milestone of a median concentration of 0.209 mg/L, representing the 50th percentile of the median TP concentrations for stream chemistry stations located in the Level IV Ecoregion of the Loess and Glacial Drift Hills (47i). Should the biological community fail to respond to Phase I reductions in total phosphorus, Phase II will commence with a TP milestone of a median concentration of 0.174 mg/L, representing the lower quartile of the median TP concentrations for stream chemistry stations located in the Level IV Ecoregion of the Loess and Glacial Drift Hills (47i; **Table 13**). Simultaneous achievement of the chlorophyll *a*, dissolved oxygen, oxygen saturation, and pH endpoints will signal phosphorus reductions are addressing the accelerated succession of aquatic biota and the development of objectionable concentrations of algae and algae byproducts thereby restoring the domestic water supply, aquatic life, and contact recreation uses in the creek.

Table 13. Total Phosphorus (TP) at current condition (2000 through 2018) and Phase I and Phase II TP milestones for Delaware River Watershed above Perry Lake.

Stream Chemistry Station	**Current Condition**	**TMDL Phase I**		**TMDL Phase II**	
	Median TP (mg/L)	TP Milestone (mg/L)	Reduction in TP from Current Concentration	TP Milestone (mg/L)	Reduction in TP from Current Concentration
Delaware River (SC554)	0.215	0.209	3%	0.174	19%
Grasshopper Creek (SC603)	0.217	0.209	4%	0.174	20%
Elk Creek (SC604)	0.240	0.209	13%	0.174	28%
Straight Creek (SC686)	0.180	0.209	-	0.174	3%

3. SOURCE INVENTORY AND ASSESSMENT

Point Sources

There are a total of 24 National Pollution Discharge Elimination System (NPDES) permits in the Delaware River Watershed above Perry Lake (**Table 14**). Of the 24 permitted facilities, six are in the contributing area for SC554 located on the Delaware River near Half Mound. Five are in the Grasshopper Creek watershed (SC603), eight are in the Elk Creek watershed (SC604), and five are in the Straight Creek watershed. Of the 24 permitted facilities, nine are discharging lagoons, five are non-discharging lagoons, two are industrial, two are municipal mechanical, two are water treatment plants, two are ready-mix plants, one is a quarry, and one permit is for a municipal site operating both a mechanical plant and a discharging lagoon.

In the contributing area of the Delaware River near Half Mound (SC554), four of the six facilities are permitted to discharge. Two facilities are discharging municipal lagoon systems that are required to monitor for total phosphorus in their effluent, quarterly when discharging. As discharging lagoons, these facilities are considered contributors to the total phosphorus load at SC554; hence, they are assigned Phase I and Phase II wasteload allocations for total phosphorus. There is one municipal mechanical plant in the watershed, City of Sabetha Wastewater Treatment Facility, that has been assigned a wasteload allocation. The only industrial facility in the watershed is a concrete plant is not expected to contribute to the phosphorus impairment in the watershed.

In the Grasshopper Creek watershed (SC603), five facilities are permitted to discharge. Three facilities are discharging municipal lagoon systems that are required to monitor for total phosphorus in their effluent, quarterly when discharging. As discharging lagoons, these facilities are considered contributors to the total phosphorus load at SC603; hence, they are assigned Phase I and Phase II wasteload allocations for total phosphorus. There is one municipal mechanical plant in the watershed, City of Horton Wastewater Treatment, that has been assigned a wasteload allocation. There is one is industrial facility in the watershed. It is Horton Municipal Power Plant, where untreated water is circulated through the single-phase heat exchangers for cooling of a diesel electric generator. It has been assigned Phase I and Phase II wasteload allocations.

In the Elk Creek watershed (SC604), five of eight facilities are permitted to discharge. There is one municipal mechanical wastewater treatment plant discharging to the Elk Creek above SC604: The City of Holton is required to monitor total phosphorus in their effluent monthly. They have been assigned a Phase I wasteload allocation under this TMDL. Of the four industrial facilities in the watershed there is an industrial waste water treatment system, a drinking water treatment facility, a quarry, and a ready-mix concrete facility in this watershed. The industrial waste water treatment system and the drinking water treatment facility have been assigned Phase I and Phase II wasteload allocations calculated but are expected to be insignificant contributors to the load seen at SC604 and should be monitored to assess. The quarry and ready-mix facilities in the watershed are not expected to contribute to the phosphorus impairment in the watershed.

In the Straight Creek watershed (SC686), five facilities are permitted to discharge. Four are discharging lagoons. City of Goff, City of Netawaka, City of Wetmore, and Jackson Heights. School. These facilities do not have reported current flows. They have been assigned a Phase I and Phase II wasteload allocation under this TMDL. There is one industrial facility in this watershed, a drinking water treatment facility. This facility is assigned a wasteload allocation.

Municipal Separate Storm Sewer System Dischargers

There are no Municipal Separate Storm Sewer System (MS4) permits within the Delaware River watershed above Perry Lake.

Table 14. National Pollution Discharge Elimination System (NPDES) facilities in the Delaware River Watershed above Perry Lake.

Permitee	Kansas Permit Number	NPDES Permit Number	Facility Type	Receiving Stream	Permit Expiration	TP Monitoring Frequency	Current Flow (MGD)	Design Flow (MGD)	Current TP Mean (mg/L)
Delaware River Watershed (SC554)									
CITY OF MUSCOTAH	M-KS48-OO01	KS0085707	Discharging Lagoon	Delaware River	12/31/2021	Quarterly	No Data	0.0248	No Data
CITY OF WHITING	M-KS81-OO01	KS0083372	Discharging Lagoon	Negro Creek via Unnamed Tributary	3/31/2020	Quarterly	No Data	0.023	1.55
CITY OF SABETHA	M-KS65-OO02	KS0096245	Mechanical	Delaware River	11/30/2021	Monthly	0.33	0.75	2.35
MIDWEST READY MIX - SABETHA	I-KS65-PR02	KSG110257	Ready Mix Plant	Delaware River via Unnamed Tributary	9/30/2022	Current permit does not require TP monitoring	No Data	NA	No Data
KICKAPOO TRUCK STOP WWTF	C-KS24-NO01	KSJ000113	Non-Discharging Lagoon	NA	11/30/2021	NA	NA	NA	NA
USC, LLC	I-KS65-NP01	KSJ000620	Non-Discharging Lagoon	NA	8/31/2022	NA	NA	NA	NA
Grasshopper Creek Watershed (SC603)									
CITY OF EVEREST	M-KS18-OO01	KS0027171	Discharging Lagoon	Otter Creek via Unnamed Tributary	12/31/2020	Quarterly	No Data	0.0325	1.49
CITY OF HURON	M-KS26-OO01	KS0047473	Discharging Lagoon	Delaware River Via Little Grasshopper Creek via Unnamed Tributary	12/31/2021	Quarterly	No Data	0.0106	1.58
CITY OF POWHATTAN	M-KS60-OO01	KS0081540	Discharging Lagoon	Delaware River via Unnamed Tributary	12/31/2021	Quarterly	No Data	0.012	1.24
CITY OF HORTON	M-KS24-OO01	KS0047465	Mechanical	Delaware River via Grasshopper Creek	6/30/2020	Monthly	0.228	0.248	3.64

Permitee	Kansas Permit Number	NPDES Permit Number	Facility Type	Receiving Stream	Permit Expiration	TP Monitoring Frequency	Current Flow (MGD)	Design Flow (MGD)	Current TP Mean (mg/L)
HORTON MUNICIPAL POWER PLANT	I-KS24-CO01	KS0092185	Industrial	Grasshopper Creek via Little Lake Municipal Reservoir L-43	11/30/2021	NA	NA	0.281	NA
Elk Creek Watershed (SC604)									
BANNER CREEK LLC.	I-KS23-PO01	KS0003271	Industrial	Kansas River via Delaware River via Elk Creek via Banner Creek	12/31/2021	Monthly	0.187	0.279	1.93
CITY OF HOLTON	M-KS23-OO03	KS0097951	Municipal Mechanical	Elk Creek & Banner Creek	3/31/2020	Monthly	0.430	0.66	2.2
			Discharging Lagoon	Elk Creek & Banner Creek	3/31/2020	Monthly	0.084		No Data
CONCRETE SUPPLY OF TOPEKA-HOLTON	I-KS23-PR01	KSG110138	Ready Mix Plant	Unnamed Tributary to Banner Creek to Elk Creek	9/30/2022	Current permit does not require TP monitoring	No Data	NA	No Data
HAMM - SMITH #106	I-KS08-PO01	KS0097632	Quarry	Kansas River via Delaware River via Elk Creek via Banner Creek via Unnamed Tributary	5/31/2020	Current permit does not require TP monitoring	No Data	0	No Data
PUBLIC WHOLESALE WATER DIST #18	I-KS23-PO03	KS0096695	Water Treatment Plant	Kansas River via Banner Creek via Unnamed Tributary	12/30/2020	Current permit does not require TP monitoring	No Data	0	No Data
WATERFALL RESTAURANT	C-KS23-NO02	KSJ000585	Non-Discharging Lagoon	NA	10/31/2022	NA	NA	NA	NA
IRELAND CUSTOM EXHAUST	C-KS23-NO01	KSJ000584	Non-Discharging Lagoon	NA	11/30/2022	NA	NA	NA	NA
CITY OF CIRCLEVILLE	M-KS08-NO01	KSJ000406	Non-Discharging Lagoon	NA	5/31/2022	NA	NA	NA	NA
Straight Creek Watershed (SC686)									
CITY OF GOFF	M-KS21-OO01	KS0047449	Discharging Lagoon	Spring Creek via Unnamed Tributary	6/30/2020	Current permit does not require TP monitoring	No Data	0.014	No Data
CITY OF NETAWAKA	M-KS49-OO01	KS0081591	Discharging Lagoon	Delaware River via Straight Creek via Spring Creek via Unnamed Tributary	3/31/2020	Current permit does not require TP monitoring	No Data	0.015	No Data

Permitee	Kansas Permit Number	NPDES Permit Number	Facility Type	Receiving Stream	Permit Expiration	TP Monitoring Frequency	Current Flow (MGD)	Design Flow (MGD)	Current TP Mean (mg/L)
CITY OF WETMORE	M-KS78-OO02	KS0099431	Discharging Lagoon	Spring Creek via Unnamed Tributary	12/31/2021	Current permit does not require TP monitoring	No Data	0.0588	No Data
USD #335 JACKSON HTS. SCHOOLS	M-KS23-OO02	KS0094528	Discharging Lagoon	Straight Creek via Unnamed Tributary	6/30/2020	Current permit does not require TP monitoring	No Data	0.016	No Data
JACKSON COUNTY RWD #3	I-KS49-PO01	KS0096059	Water Treatment Plant	Kansas River via Straight Creek via Unnamed Tributary	11/30/2022	Current permit does not require TP monitoring	No Data	0.0012	No Data

Livestock and Waste Management Systems

There are 56 certified or permitted Confined Animal Feeding Operations (CAFOs) within the Delaware River Watershed above Perry Lake (**Table 15)**. Two of these facilities are large enough to require a federal permit. All these livestock facilities have waste management systems designed to retain an anticipated two weeks of normal wastewater from their operations and contain a 25-year, 24-hour rainfall/runoff event, as well. Typically, this rainfall event coincides with streamflow that occurs less than 1-5% of the time. Additionally, facility waste management systems are designed to minimize runoff entering operations and detain runoff emanating from operations. It is unlikely TP loading would be attributable to properly operating permitted facilities, though extensive loading may occur if any of these facilities were in violation and discharged.

Table 15. Confined Animal Feeding Operations in the Delaware River Watershed.

Kansas Permit Number	County	Livestock Type	Livestock Total	Permit Type
A-KSNM-B006	Nemaha	Beef	400	Application
A-KSNM-BA01	Nemaha	Beef	400	Certification
A-KSNM-BA06	Nemaha	Beef	70	Certification
A-KSBR-BA08	Brown	Beef	110	Certification
A-KSBR-BA09	Brown	Beef, Horses	292	Certification
A-KSBR-BA05	Brown	Beef	100	Certification
A-KSBR-BA04	Brown	Beef	600	Certification
A-KSNM-BA04	Nemaha	Beef	300	Certification
A-KSBR-BA10	Brown	Beef	300	Certification
A-KSBR-BA06	Brown	Beef	150	Certification
A-KSBR-BA03	Brown	Beef	300	Certification
A-KSJA-BA09	Jackson	Beef	500	Certification
A-KSJA-MA08	Jackson	Dairy	60	Certification
A-KSJA-BA07	Jackson	Beef	590	Certification

Kansas Permit Number	County	Livestock Type	Livestock Total	Permit Type
A-KSJA-BA05	Jackson	Beef	300	Certification
A-KSJA-BA06	Jackson	Beef	150	Certification
A-KSJA-SA02	Jackson	Swine, Beef	291	Certification
A-KSNM-S024	Nemaha	Swine, Beef	1760	Permit
A-KSNM-S023	Nemaha	Swine, Beef	1420	Permit
A-KSNM-M004	Nemaha	Dairy	150	Permit
A-KSNM-S031	Nemaha	Swine	1200	Permit
A-KSNM-S008	Nemaha	Swine, Beef	555	Permit
A-KSBR-S025	Brown	Swine	900	Permit
A-KSNM-S022	Nemaha	Swine, Beef	772	Permit
A-KSNM-S015	Nemaha	Swine	2760	Permit
A-KSNM-S035	Nemaha	Swine	2400	Permit
A-KSNM-S040	Nemaha	Swine	2490	Permit
A-KSBR-M006	Brown	Dairy	362	Permit
A-MOBR-S012	Brown	Swine	800	Permit
A-KSNM-C001*	Nemaha	Beef	1450	Permit
A-KSNM-S021	Nemaha	Swine, Beef	335	Permit
A-KSNM-B003	Nemaha	Beef	900	Permit
A-KSJA-B008	Jackson	Beef	999	Permit
A-KSJA-M016	Jackson	Dairy	125	Permit
A-KSJA-B004	Jackson	Beef, Swine	740	Permit
A-KSJA-S018	Jackson	Swine, Beef	980	Permit
A-KSAT-B002	Atchison	Beef	50	Permit
A-KSAT-C001*	Atchison	Beef	4999	Permit
A-KSAT-B001	Atchison	Beef	45	Permit
A-KSJA-B002	Jackson	Beef, Horses	132.2	Permit
A-KSJA-S011	Jackson	Beef	250	Permit
A-KSJA-M003	Jackson	Dairy	70	Permit
1385	Nemaha	Swine	2400	Registration
1373	Nemaha	Swine	2500	Registration
A-KSNM-S042	Nemaha	Swine	2490	Registration
1172	Brown	Beef	500	Registration
1386	Nemaha	Beef	1450	Registration
A-KSNM-BA07	Nemaha	Beef	560	Registration
A-KSJA-M017	Jackson	Dairy	18	Registration
A-KSNM-M011	Nemaha	Dairy	230	Renewal
A-KSBR-M002	Brown	Dairy	246	Renewal
A-KSBR-B002	Brown	Beef	350	Renewal
A-KSNM-S032	Nemaha	Swine	2400	Renewal
A-KSJA-B003	Jackson	Beef	40	Renewal
A-KSJA-K003	Jackson	Kennel	800	Renewal
A-KSJA-M013	Jackson	Dairy	215	Renewal

*= federally permitted facility

The total number of livestock within Atchison, Brown, and Jackson counties declined, while it increased in Nemaha county between 2007 and 2012 (**Table 16**; U.S. Department of Agriculture, 2007, 2012). The primary livestock industry is cattle in every county expect Nemaha, which is

primarily hogs and pigs. From 2007 to 2012, most livestock numbers decreased except in Nemaha county where census data shows hog and pig numbers increased by approximately 63%. Smaller, unregistered livestock and winter-feeding operations that may be located directly adjacent to streams and contributing tributaries in the watershed which can contribute significant nutrient loads to the watershed particularly during runoff events.

Table 16. Agricultural census results for livestock in Atchison, Brown, Jackson, and Nemaha counties from 2007 and 2012 (U.S. Department of Agriculture, 2012).

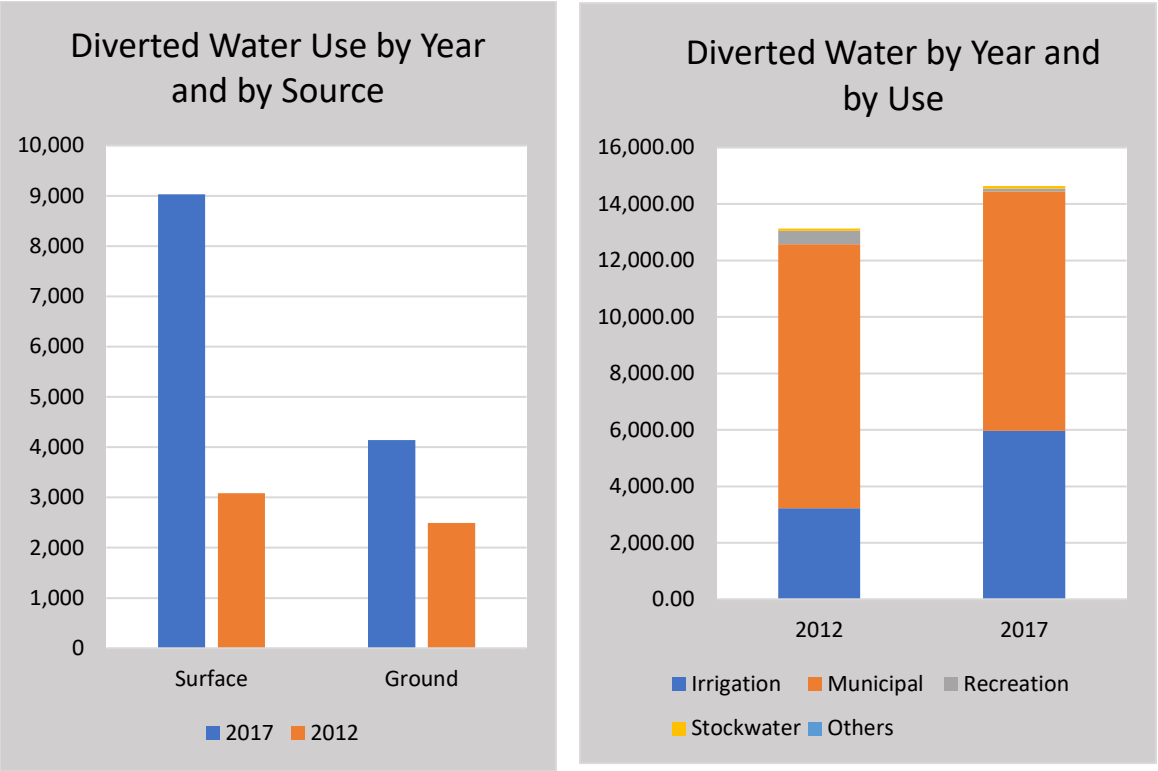
Livestock	Atchison 2007	Atchison 2012	Brown 2007	Brown 2012	Jackson 2007	Jackson 2012	Nemaha 2007	Nemaha 2012
Cattle and Calves	35,656	26,909	29,122	18,693	50,453	47,601	66,730	54,373
Sheep and Lambs	-	116	1,664	966	284	253	607	499
Poultry	622	1,335	348	529	1,413	3,971	1,339	733
Hogs and Pigs	4,442	1,687	6,663	2,557	1,949	680	121,191	197,430
Goats	32	515	197	102	694	596	89	300
Total	**36,752**	**30,562**	**37,994**	**22,847**	**54,793**	**53,101**	**189,956**	**253,335**

Definition: – - data not available

Points of Diversion

Within Atchison, Brown, Jackson, and Nemaha counties, there are 497 unique water rights and 767 unique points of diversion. In these counties, surface water is diverted in greater quantities than groundwater (**Figure 15**; Water Information Management and Analysis System, 2019). This is especially notable during dry years, such as 2012. The predominant use for diverted water in these counties is municipal with significant use of the Delaware River. Additional diversions for irrigation and recreation uses tend to vary based on environmental conditions; irrigation increases by several thousand-acre feet from a dry year to an average year, as demonstrated in 2017.

Figure 15. Diverted water by source and use according to the Water Information Management and Analysis System (WIMAS) for a dry (2012) and wet (2017) year for the Delaware River TMDL Watershed.



Land Use

The total number of farms and acres of cropland declined in Atchison, Brown, Jackson, and Nemaha counties between 2007 and 2012. In these counties there were 286 less farms in cropland and 57,212 less acres of cropland in 2012 than in 2007 (**Table 17**; U.S. Department of Agriculture, 2007, 2012). The fertilizers used in the counties is higher in counties with higher total cropland acres such as Brown and Nemaha counties. The total value of fertilizers, including lime and soil conditioners, applied in 2012 in counties within the Delaware River watershed above Perry Lake is $57,101,000 (**Table 18).** The 2011 National Land Cover Database shows the dominant land use is grassland (54.4%) and the secondary land use is cultivated crops (29.5%) in the watershed (**Table 19**; **Figure 38**; NLCD, 2011). Cultivated cropland has an increased potential for nutrient runoff from fertilizers, which can contribute to TP loads in the watershed. Additionally, 4.8% of the watershed is developed, with the most development occurring near Holton and Horton. Built infrastructure and impervious surfaces in urban environments increase runoff, which can potentially contribute to TP loads in the watershed, as well.

Table 17. Agricultural census results for farms and cropland in Atchison, Brown, Jackson, and Nemaha counties from 2007 and 2012 (U.S. Department of Agriculture, 2012).

County	Total Farms in Cropland 2007	Total Cropland (acres) 2007	Total Farms in Cropland 2012	Total Cropland (acres) 2012
Atchison	548	157,253	497	135,865

County	Total Farms in Cropland 2007	Total Cropland (acres) 2007	Total Farms in Cropland 2012	Total Cropland (acres) 2012
Brown	510	238,767	403	217,158
Jackson	747	114,371	705	116,005
Nemaha	816	248,234	730	232,385
Total	**2,621**	**758,625**	**2,335**	**701,413**

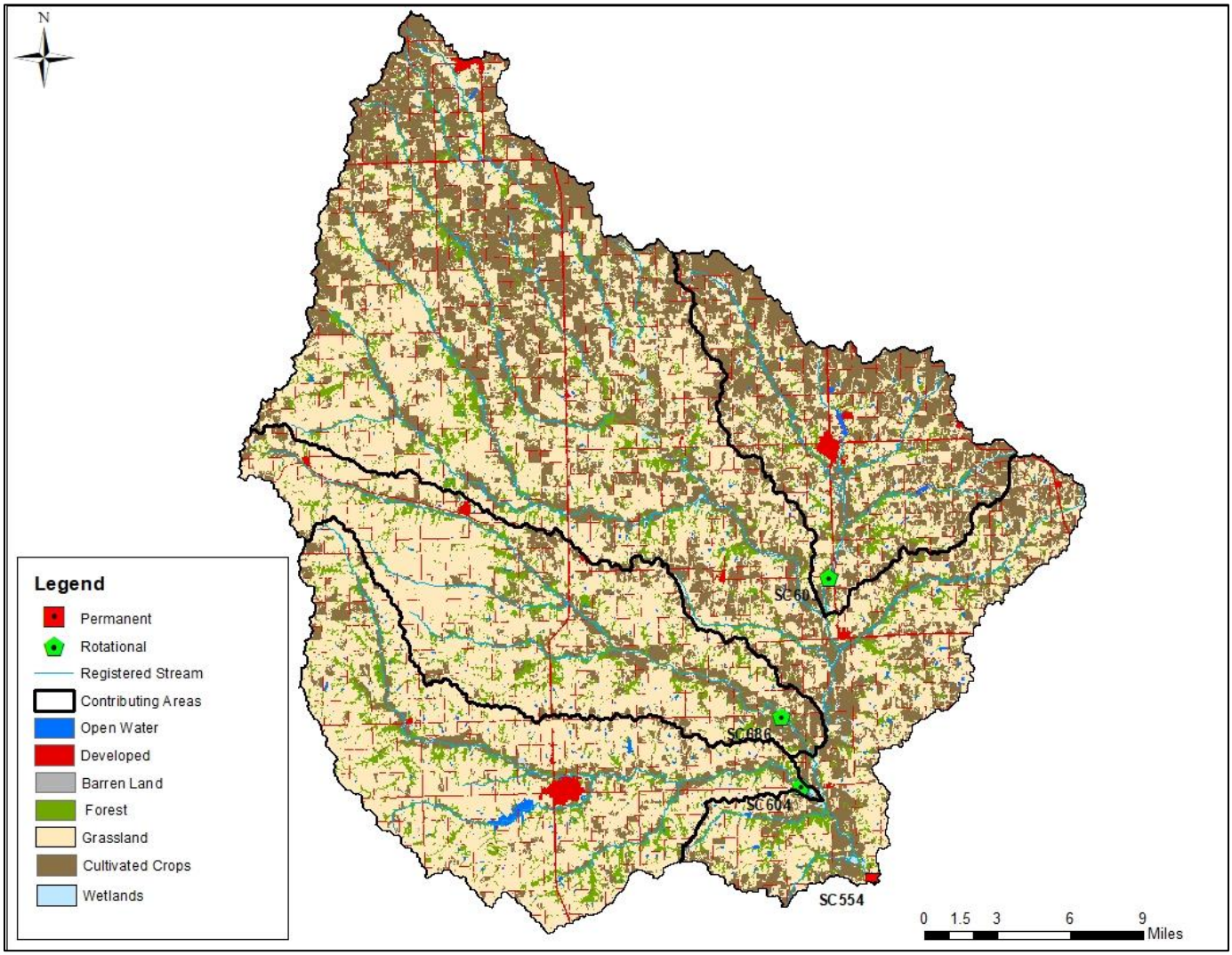
Table 18: Dollar value of fertilizer, including lime and soil conditioner, applied in Atchison, Brown, Jackson, and Nemaha counties in 2012 (U.S. Department of Agriculture, 2012).

County	Value of Fertilizer Applied in County
Atchison	$10,806,000
Brown	$18,135,000
Jackson	$7,649,000
Nemaha	$20,511,000
Total	**$57,101,000**

Table 19. Land cover by percent in the Delaware River Watershed above Perry Lake (NLCD, 2011).

Watershed	**Cultivated Crops (%)**	**Grassland (%)**	**Developed Land (%)**	**Open Water (%)**	**Forest (%)**	**Wetlands (%)**	**Barren Land (%)**
Delaware River (SC554)	35.3	49.3	4.5	0.8	9.3	0.8	0.0
Grasshopper Creek (SC603)	48.0	37.1	6.2	1.2	6.8	0.6	0.0
Elk Creek (SC604)	11.8	68.9	5.3	1.6	12.0	0.4	0.0
Straight Creek (SC686)	17.4	67.1	4.2	0.6	10.3	0.3	0.0
Total	29.5	54.4	4.8	1.0	9.7	0.6	0.0

Figure 38. Map of land cover in the Delaware River Watershed above Perry Lake (NLCD, 2011).



Population Density

Population within the counties where the watershed lies is on the decline in Brown and Nemaha according to the 2000 and 2010 censuses and slightly increasing in Atchison and Jackson counties (**Table 20**). The largest cities in the watershed have the following populations at the 2010 Census: Holton 3,329; Horton 1,776; and Sabetha 2,571.

Table 20. County census results from 2000 and 2010 (U.S. Census Bureau, 2010).

County	Population, 2000	Population, 2010	Population Change, 2000 to 2010 (%)
Atchison	16,774	16,924	0.9
Brown	10,724	9,984	-6.9
Jackson	12,657	13,462	6.3
Nemaha	10,717	10,178	-5.0

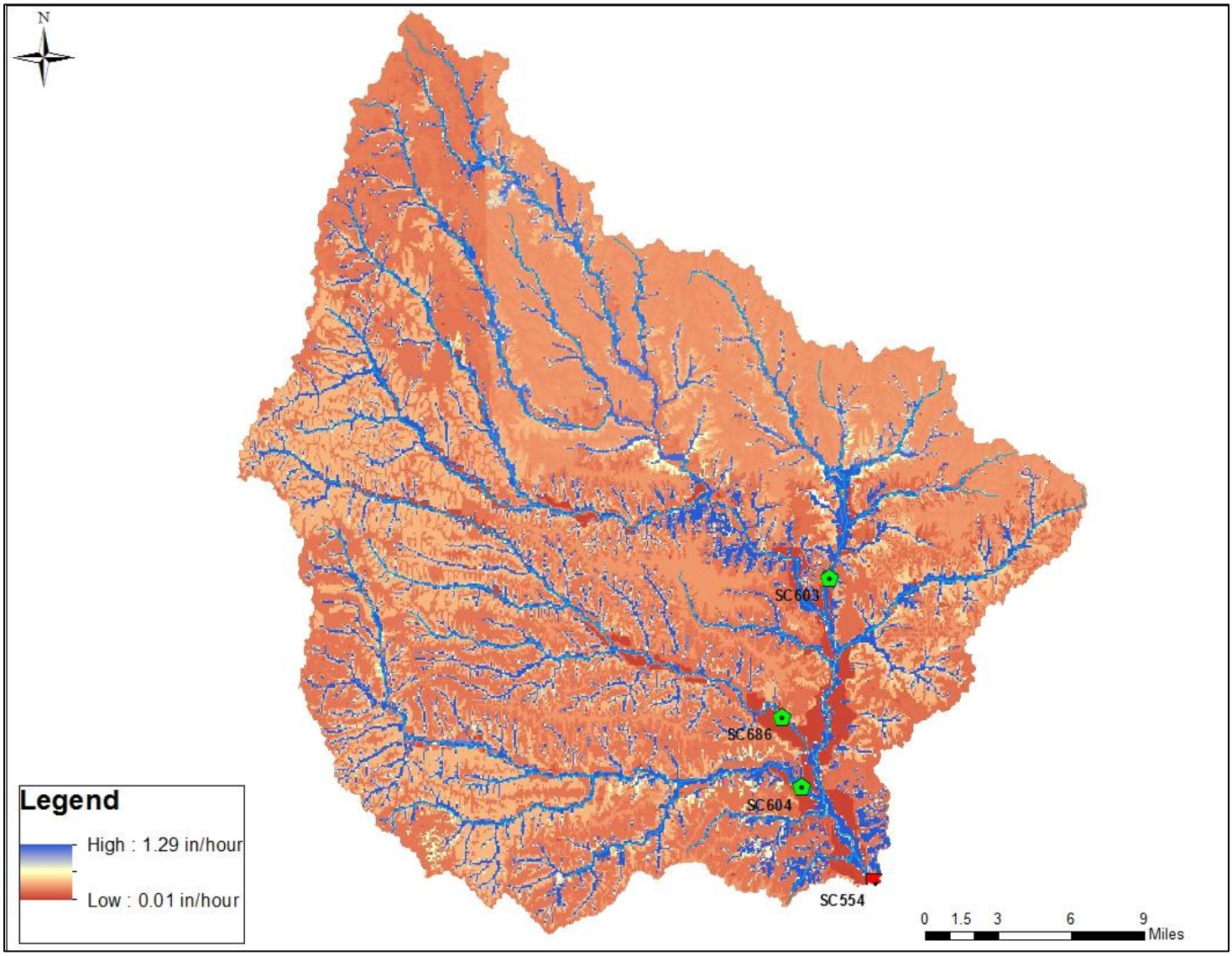
On-Site Waste Systems

The population of the Delaware River Watershed above Perry Lake is predominantly rural. Urban populations are typically served by municipal sewer systems; however, rural populations may not be connected to the municipal sewer system. According to the U.S. Environmental Protection Agency's Spreadsheet Tool for Estimating Pollutant Load (STEPL), there are a total of 2,339 septic systems located in the Delaware River Watershed above Perry Lake. Septic systems in the state of Kansas typically have an estimated 10-15% failure rate (Electric Power Research Institute provided by U.S. Environmental Protection Agency, 2017). Failing on-site septic systems have the potential to contribute to nutrient loading in the watershed. However, because of their small flows and the proclivity of phosphorus to adsorb to soil, failing on-site septic systems are considered a minor source of TP loading within the watershed and are not expected to significantly contribute to the TP impairment in the Delaware River Watershed above Perry Lake.

Contributing Runoff

Runoff is primarily generated as infiltration excess with rainfall intensities greater than soil permeability. As the watershed's soil profiles become saturated, excess overland flow is produced. According to the NRCS STATSGO database, the Delaware River watershed above Perry Lake has a mean soil permeability of 0.40 inches/hour (**Figure 39**). Permeability in the watershed ranges from 0.01 to 1.29 inches/hour with approximately 54.3% of the watershed having an extremely low soil permeability of 0.57 inches/hour. According to a USGS open-file report, the threshold soil-permeability values are set at 3.43 inches/hour for very high, 2.86 inches/hour for high, 2.29 inches/hour for moderate, 1.71 inches/hour for low, 1.14 inches/hour for very low, and 0.57 inches/hour for extremely low soil-permeability (Juracek, 2000). Approximately 65.3% of the Delaware River watershed above Perry Lake is below the very low (1.14 inches/hour) threshold. Runoff is primarily generated as infiltration excess with rainfall intensities greater than soil permeability. As the watershed's soil profiles become saturated, excess overland flow is produced.

Figure 39. Map of Natural Resources Conservation Service State Soil Geographic Database soil permeability in the Delaware River Watershed above Perry Lake.



Background Levels

Phosphorus is present over the landscape and in the soil profile. It is also present in terrestrial and aquatic biota. Wildlife can contribute to phosphorus loadings, particularly if they congregate to a density that exceeds the assimilative capacity of the land or water.

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

The endpoints for these TMDLs are based on the biological condition, pH, sestonic chlorophyll *a*, and dissolved oxygen concentrations, all of which should improve to a level of full attainment of designated uses as phosphorus concentrations decrease in the Delaware River and its tributaries above Perry Lake. Incremental loads for the contributing area to SC554 can be assessed by subtracting the tributary loads seen at SC686, SC604, and SC603 from SC554 loads.

These TMDLs are established in two phases to reduce phosphorus loadings and total phosphorus concentrations with periodic assessment of the biological condition within the Delaware River and its tributaries. The Phase I TP milestone is set at 0.209 mg/L, which is the 50th percentile of the median concentrations of KDHE SC stations within the Level IV Ecoregion of the Loess and Glacial Drift Hills (47i). It is expected the initial application of riparian and livestock agricultural best management practices in the watershed will abate and reduce total phosphorus loading from nonpoint sources during Phase I implementation. Presuming one or more of the endpoints are not met at the end of Phase I, Phase II will commence with a TP milestone of 0.174 mg/L, which is the 25th percentile of the median concentrations of KDHE SC stations within the Level IV Ecoregion of the Loess and Glacial Drift Hills (47i). Further reductions in TP concentrations and loads for Phase II will be accomplished through enhanced implementation of controls nonpoint sources in the watershed. For both Phase I and Phase II, total load capacities are calculated according to the previously described TP milestones and the flow conditions in the Delaware River TMDL Watersheds.

For purposes of comparing current TP loading conditions in the river to the expected reduction in TP loading, the current condition was evaluated using the median TP concentration at each SC station from 1990 to 2018. Sampled TP concentrations at all four stations were converted to loads for seasonal comparison with their respective TMDLs.

Point Sources

The Phase I and Phase II wasteload allocation (WLA) associated with the facilities discharging in the watershed are detailed in **Table 21.** The total Phase I TP WLA for the Delaware River TMDL watershed is 18.33 lbs/day. The total Phase II TP WLA for the Delaware River TMDL watershed is 11.41 lbs/day. Wasteload allocations are calculated for each facility according to the following: non-discharging lagoons, quarries, and concrete operations are calculated at 0 lbs/day for Phase I and Phase II; discharging lagoons are calculated at a TP concentration of 2 mg/L for Phase I and Phase II, an effluent concentration common in Kansas lagoons. Industrial facilities and water treatment plants are calculated at a TP concentration of 0.2 mg/L for Phase I and Phase II. Phase I wasteload allocations for municipal mechanical WWTF are calculated at a TP concentration of 1 mg/L; Phase II wasteload allocations for municipal mechanical WWTF are calculated at a TP concentration of 0.5 mg/L. The TP WLAs assigned to all permitted facilities are based upon current design flows for each facility.

Delaware River (SC554) Watershed
The three facilities assigned a Phase I and Phase II TP WLA concentration of 0 lbs/day are the two non-discharging lagoons operated by Kickapoo Truck Stop, USC, LLC, and Midwest Ready Mix. The Phase I and Phase II WLA for two discharging lagoon systems operated by the City of Muscotah and the City of Whiting are calculated with the TP WLA concentration of 2 mg/L at design flow. The remaining facility within this watershed is the municipal mechanical WWTF operated by the City of Sabetha that currently operates at 0.33 MGD. Currently the discharge from the City of Sabetha WWTF is 2.35 mg/L. The Phase I TP WLA is established at a concentration of 1 mg/L resulting in a wasteload allocation that will require reduction from current loading to meet. Phase II will require further reductions with a WLA calculated at design flow and a TP concentration of 0.5 mg/L.

Grasshopper Creek (SC603) Watershed
The Phase I and Phase II WLA for three discharging lagoon systems operated by the City of Everest, the City of Huron, and the City of Powhattan are calculated with the TP concentration of 2 mg/L at facility design flow. There is one industrial facility which is the Horton Municipal Power Plant. The Phase I and Phase II TP WLA was calculated for this facility at 0.2 mg/L at design flow. The remaining facility within this watershed is the municipal mechanical WWTF operated by the City of Horton that currently operates at 0.228 MGD. Currently the discharge from the City of Horton WWTF is 3.64 mg/L. The Phase I TP WLA is established at a concentration of 1 mg/L at design flow resulting in a wasteload allocation that will require reduction from current loading to meet. Phase II will require further reductions with a WLA calculated at design flow and a TP concentration of 0.5 mg/L.

Elk Creek (SC604) Watershed
The five facilities assigned a Phase I and Phase II TP WLA concentration of 0 lbs/day are the concrete operations operated by Concrete Supply of Topeka – Holton, a quarry operated by Hamm- Smith #106, and the non-discharging lagoons operated by the city of Circleville, Ireland Custom Exhaust, and the Waterfall Restaurant. The Phase I and Phase II WLA calculated at 0.2 mg/L TP at design flow are for the industrial facility operated by Banner Creek LLC and the water treatment plant operated by Public Wholesale Water District #18. The remaining facility within this watershed is the municipal mechanical WWTF operated by the City of Holton that currently operates at 0.514 MGD. Currently the discharge from the City of Holton WWTF is 2.20 mg/L. The Phase I TP WLA is established at a concentration of 1 mg/L at design flow resulting in a wasteload allocation that will require reduction from current loading to meet. Phase II will require further reductions with a WLA calculated at design flow and a TP of 0.5 mg/L.

Straight Creek (SC686) Watershed
The Phase I and Phase II WLA for four discharging lagoon systems operated by the City of Goff, the City of Netawaka, USD #335 Jackson Heights Schools, and the City of Wetmore are calculated with the TP WLA concentration of 2 mg/L at design flow. The remaining facility within this watershed is a water treatment plant operated by Jackson County Rural Water District

#3. The Phase I and Phase II WLA for this facility is calculated with a TP concentration of 0.2 mg/L and design flow.

Reserve Wasteload Allocation

In addition, a reserve WLA of 3 lbs/day totaling 1,095 lbs/year total phosphorus has been reserved in anticipation of further development within the watershed. The reserve WLA may be portioned and applied to new or expanded discharge within any one of the watersheds contributing to SC554, SC603, SC604, or SC686.

Table 21. Phase I total phosphorus wasteload allocations for National Pollution Discharge Elimination System (NPDES) permitted facilities for the Delaware River TMDL Watershed.

Permittee	Kansas Permit Number	NPDES Permit Number	Facility Type	Design Flow (MGD)	Anticipated Total Phosphorus Wasteload Allocation Concentration (mg/L)	Total Phosphorus Daily Wasteload Allocation (lbs/day)	Total Phosphorus Annual Wasteload Allocation (lbs/year)
CITY OF EVEREST	M-KS18-OO01	KS0027171	Discharging Lagoon	0.0325	2	0.54	197.10
CITY OF HURON	M-KS26-OO01	KS0047473	Discharging Lagoon	0.0106	2	0.18	65.70
CITY OF POWHATTAN	M-KS60-OO01	KS0081540	Discharging Lagoon	0.012	2	0.20	73.00
HORTON MUNICIPAL POWER PLANT	I-KS24-CO01	KS0092185	Industrial	0.281	0.2	0.47	171.55
CITY OF HORTON	M-KS24-OO01	KS0047465	Mechanical	0.248	1	2.07	755.55
Total Phosphorus Wasteload Allocation for Grasshopper Creek (SC603)						**3.46**	**1,262.90**
BANNER CREEK LLC.	I-KS23-PO01	KS0003271	Industrial	0.279	0.2	0.47	171.55
CITY OF HOLTON	M-KS23-OO03	KS0097951	Municipal Mechanical and Discharging Lagoon	0.66	1	5.51	2011.15
CITY OF CIRCLEVILLE	M-KS08-NO01	KSJ000406	Non-Discharging Lagoon	NA	0	0	0
IRELAND CUSTOM EXHAUST	C-KS23-NO01	KSJ000584	Non-Discharging Lagoon	NA	0	0	0
WATERFALL RESTAURANT	C-KS23-NO02	KSJ000585	Non-Discharging Lagoon	NA	0	0	0
HAMM - SMITH #106	I-KS08-PO01	KS0097632	Quarry	Not specified	0	0	0
CONCRETE SUPPLY OF TOPEKA-HOLTON	I-KS23-PR01	KSG110138	Ready Mix Plant	Not specified	0	0	0

Permittee	Kansas Permit Number	NPDES Permit Number	Facility Type	Design Flow (MGD)	Anticipated Total Phosphorus Wasteload Allocation Concentration (mg/L)	Total Phosphorus Daily Wasteload Allocation (lbs/day)	Total Phosphorus Annual Wasteload Allocation (lbs/year)
PUBLIC WHOLESALE WATER DIST #18	I-KS23-PO03	KS0096695	Water Treatment Plant	0.06	0.2	0.10	36.50
Total Phosphorus Wasteload Allocation for Elk Creek (SC604)						**6.08**	**2,219.20**
CITY OF GOFF	M-KS21-OO01	KS0047449	Discharging Lagoon	0.014	2	0.23	83.95
CITY OF NETAWAKA	M-KS49-OO01	KS0081591	Discharging Lagoon	0.015	2	0.25	91.25
CITY OF WETMORE	M-KS78-OO02	KS0099431	Discharging Lagoon	0.0588	2	0.98	357.70
USD #335 JACKSON HTS. SCHOOLS	M-KS23-OO02	KS0094528	Discharging Lagoon	0.016	2	0.27	98.55
JACKSON COUNTY RWD #3	I-KS49-PO01	KS0096059	Water Treatment Plant	0.0012	0.2	0.0004	0.15
Total Phosphorus Wasteload Allocation for Straight Creek (SC686)						**1.73**	**631.60**
CITY OF MUSCOTAH	M-KS48-OO01	KS0085707	Discharging Lagoon	0.0248	2	0.41	149.65
CITY OF WHITING	M-KS81-OO01	KS0083372	Discharging Lagoon	0.023	2	0.38	138.70
CITY OF SABETHA	M-KS65-OO02	KS0096245	Mechanical	0.75	1	6.26	2284.90
KICKAPOO TRUCK STOP WWTF	C-KS24-NO01	KSJ000113	Non-Discharging Lagoon	NA	0	0	0
USC, LLC	I-KS65-NP01	KSJ000620	Non-Discharging Lagoon	NA	0	0	0
MIDWEST READY MIX - SABETHA	I-KS65-PR02	KSG110257	Ready Mix Plant	Not specified	0	0	0
Total Phosphorus Wasteload Allocation for Delaware River (SC554)						**7.05**	**2,573.25**
Total Phosphorus Total Reserve Wasteload Allocation						**3.00**	**1,095.00**
Total Phosphorus Total Wasteload Allocation						**21.32**	**7,781.95**

Nonpoint Source Load Allocation

The load allocation (LA) is established to account for nonpoint sources of TP in the watershed. The LA is the remainder of the load capacity (LC) after all other allocations are accounted for. Loads from nonpoint source TP are assumed to be minimal during low flow conditions and grow proportionately as flow conditions increase, thereby accounting for increased runoff during precipitation events. As the primary source of total phosphorus loading to the Delaware River Watershed is from nonpoint sources, the application of agricultural best management practices (BMPs) in riparian zones near cropland and livestock areas should be emphasized in order to abate and reduce nonpoint source TP loading in this watershed. Phase I and Phase II nonpoint

source reductions are expected to be achieved by implementation of agricultural BMPs in the Delaware River watershed as described in the Section 319 Nine Element Plan developed by the Delaware River Watershed Restoration and Protection Strategy (WRAPS) groups.

Defined Margin of Safety

The margin of safety safeguards against the uncertainty in TP loading in the Delaware River Watershed above Perry Lake. This TMDL uses conservative assumptions and relies on an implicit margin of safety. First, five endpoints are established by this TMDL to assess compliance with the narrative nutrient criteria. Secondly, the biological endpoints used to assess compliance with the narrative criteria must be maintained for three consecutive years before attainment of water quality standards can be claimed. Third, wasteloads were conservatively set by using design flow for municipal facilities, although most are discharging well under design flow and some wastewater treatment facilities were assigned wasteloads when it is likely that several do not contribute any nutrient loads.

The described TMDLs, or LCs, are delineated below for the Grasshopper Creek (SC603; **Figure 40**; **Table 22**), Elk Creek (SC604; **Figure 41**; **Table 23**), Straight Creek (SC586; **Figure 42**; **Table 24**), and the Delaware River (SC554; **Figure 43; Table 25**).

Figure 40. Total phosphorus Phase I Total Maximum Daily Load for Grasshopper Creek near Muscotah (SC603).

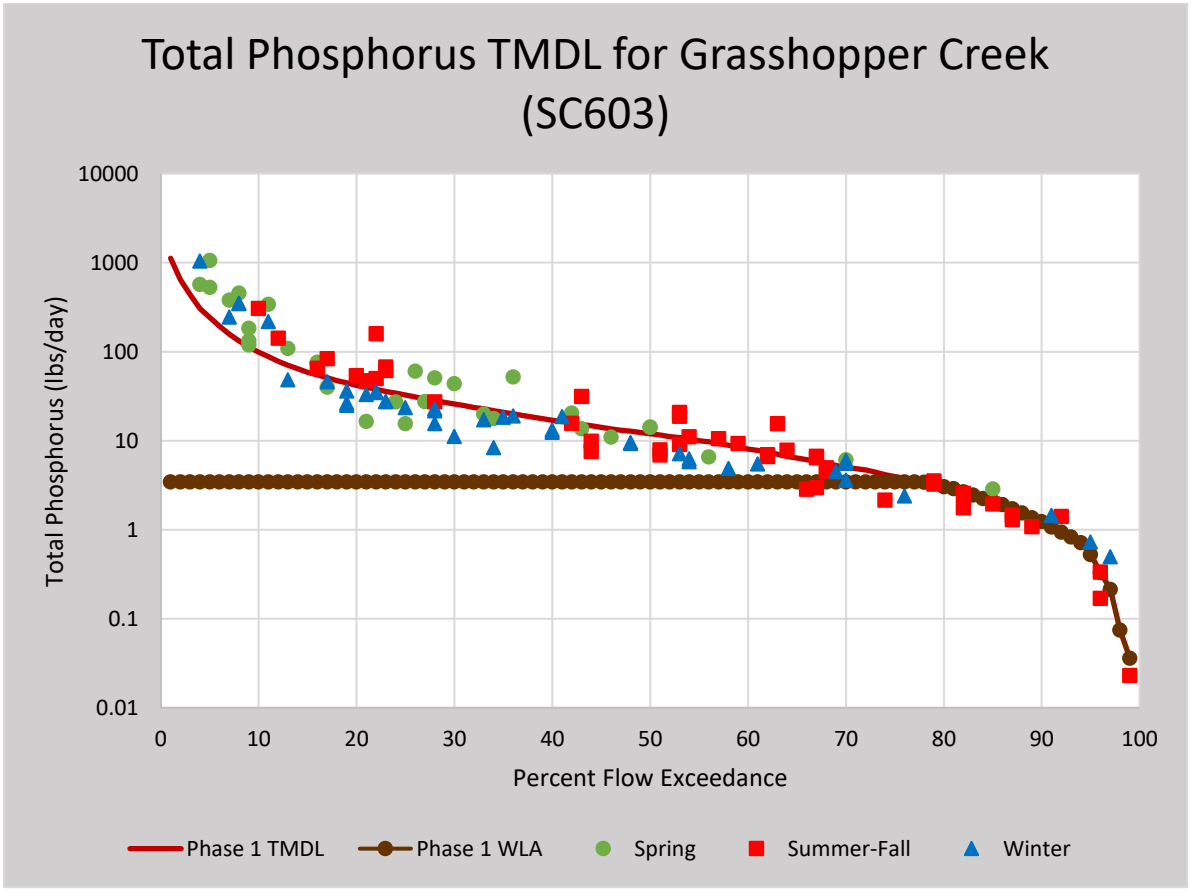


Table 22. Phase I and Phase II load capacity (TMDL) and allocations in Grasshopper Creek near Muscotah (SC603). Current condition was developed using a total phosphorus value of 0.217 mg/L, the 1990-2018 period of record median. TMDL (based upon the median total phosphorus concentration from 1990 to 2018), total load capacity, and load capacity apportionment for Grasshopper Creek near Muscotah (SC603).

Percent Flow Exceedance	Flow (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)
Phase I					
90%	1.09	1.28	1.24	1.24	0.00
75%	3.49	4.09	3.94	3.46	0.48
50%	10.58	12.39	11.94	3.46	8.48
25%	28.8	33.72	32.48	3.46	29.02
10%	87.8	102.88	99.09	3.46	95.63
Phase II					
90%	1.09	1.28	1.03	1.03	0.00
75%	3.49	4.09	3.28	2.96	0.32
50%	10.58	12.39	9.94	2.96	6.98
25%	28.8	33.72	27.04	2.96	24.08
10%	87.8	102.88	82.50	2.96	79.54

Figure 41. Total phosphorus Phase I Total Maximum Daily Load for Elk Creek near Larkinburg (SC604).

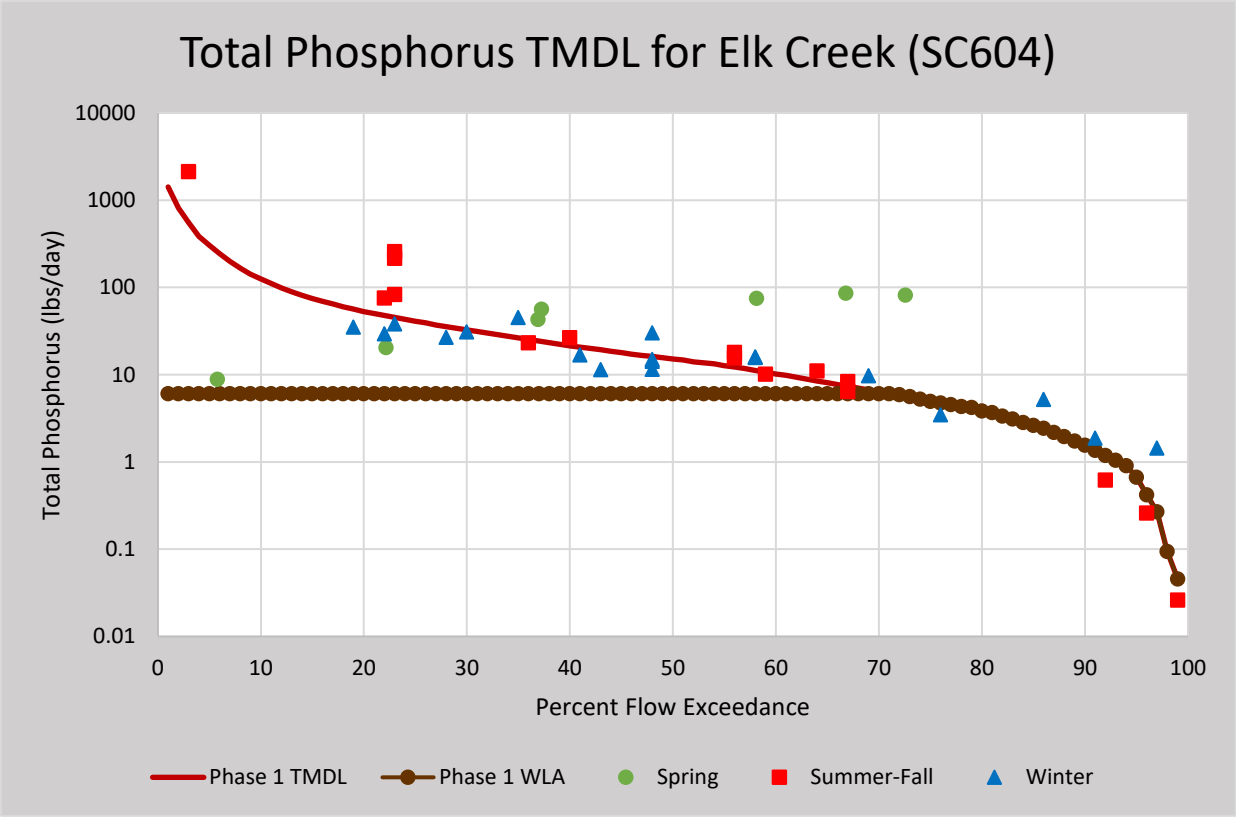


Table 23. Phase I and Phase II load capacity (TMDL) and allocations in Elk Creek near Larkinburg (SC604). Current condition was developed using a total phosphorus value of 0.240 mg/L, the 1990-2018 period of record median. TMDL (based upon the median total phosphorus concentration from 1990 to 2018), total load capacity, and load capacity apportionment for Elk Creek near Larkinburg (SC604).

Percent Flow Exceedance	Flow (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)
Phase I					
90%	1.38	1.79	1.56	1.56	0.00
75%	4.41	5.72	4.98	4.98	0.00
50%	13.37	17.33	15.09	6.08	9.01
25%	36.4	47.14	41.05	6.08	34.97
10%	111.0	143.85	125.27	6.08	119.19
Phase II					
90%	1.38	1.28	1.30	1.30	0.00
75%	4.41	4.09	4.15	4.15	0.00
50%	13.37	12.39	12.56	5.58	6.98
25%	36.4	33.72	34.18	5.58	28.60
10%	111.0	102.88	104.29	5.58	98.71

Figure 42. Total phosphorus Phase I Total Maximum Daily Load for Straight Creek near Larkinburg (SC686).

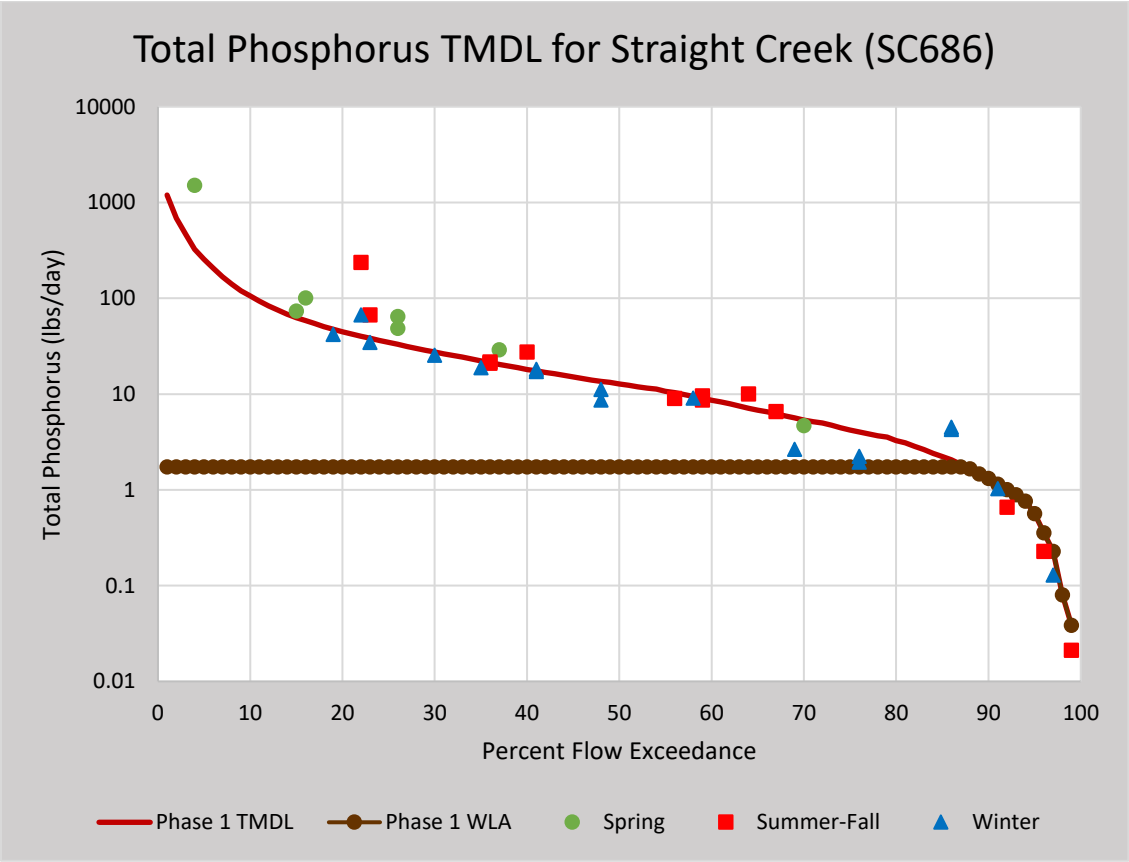


Table 24. Phase I and Phase II load capacity (TMDL) and allocations in Straight Creek near Larkinburg (SC686). Current condition was developed using a total phosphorus value of 0.180mg/L, the 1990-2018 period of record median. TMDL (based upon the median total phosphorus concentration from 1990 to 2018), total load capacity, and load capacity apportionment for Straight Creek near Larkinburg (SC686).

Percent Flow Exceedance	Flow (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)
Phase I					
90%	1.17	1.13	1.32	1.32	0.00
75%	3.72	3.62	4.20	1.74	2.46
50%	11.27	10.96	12.72	1.74	10.98
25%	30.7	29.82	34.62	1.74	32.88
10%	93.6	90.98	105.64	1.74	103.90
Phase II					
90%	1.17	1.13	1.10	1.10	0.00
75%	3.72	3.62	3.50	1.74	1.76
50%	11.27	10.96	10.59	1.74	8.85
25%	30.7	29.82	28.82	1.74	27.08
10%	93.6	90.98	87.95	1.74	86.21

Figure 43. Total phosphorus Phase I Total Maximum Daily Load for the Delaware River near Half Mound (SC554).

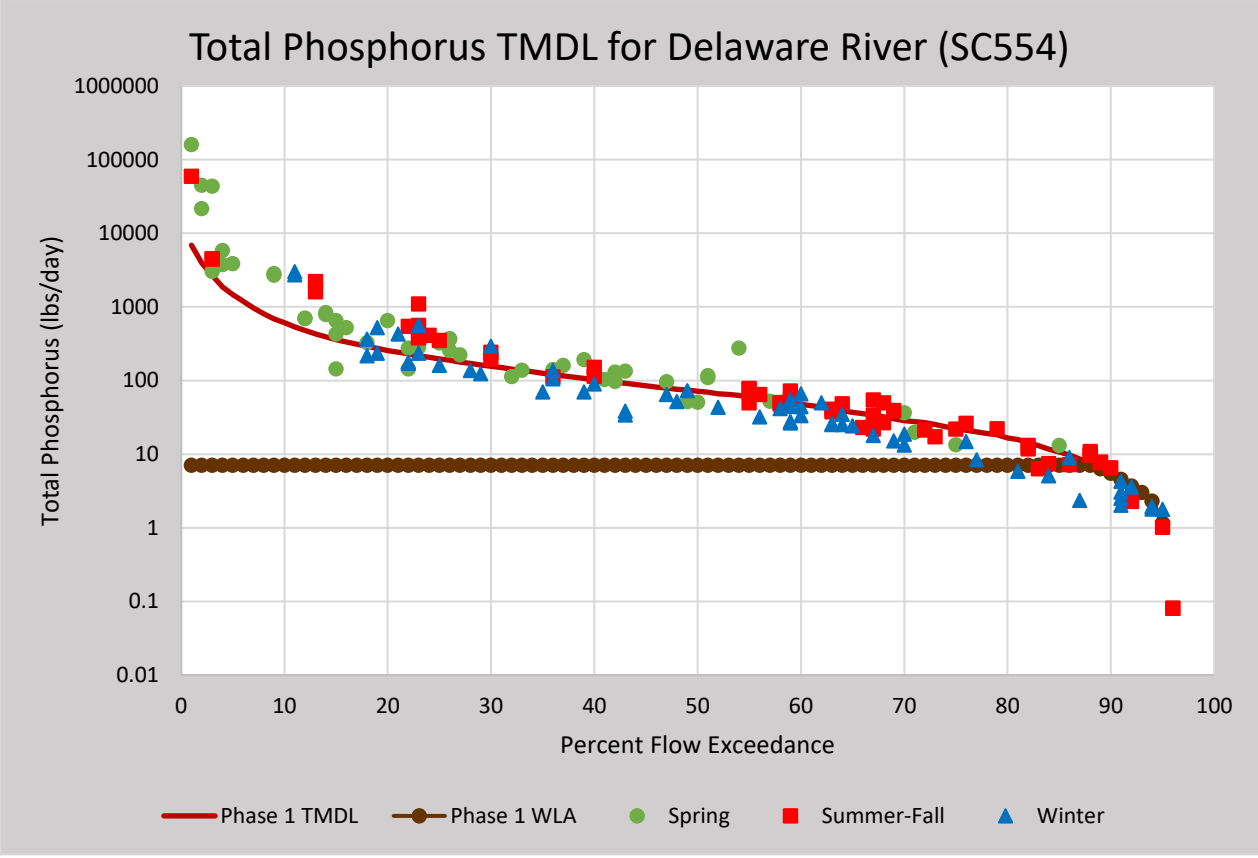


Table 25. Phase I and Phase II load capacity (TMDL) and allocations in the Delaware River near Half Mound (SC5540) to terminus. Current condition was developed using a total phosphorus value of 0.215 mg/L, the 1990-2018 period of record median. TMDL (based upon the median total phosphorus concentration from 1990 to 2018), total load capacity, and load capacity apportionment for the Delaware River near Half Mound (SC554).

Percent Flow Exceedance	Flow (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	Reserve Wasteload Allocations (lbs/day)	Load Allocation (lbs/day)
Phase I						
90%	4.87	5.66	5.50	5.50	0.00	0.00
75%	19.60	22.75	22.12	7.06	0.00	15.06
50%	63.11	73.27	71.22	7.06	3.00	61.16
25%	174.90	203.06	197.39	7.06	3.00	187.33
10%	537.50	624.00	606.58	7.06	3.00	596.52
Phase II						
90%	4.87	5.66	4.58	4.58	0.00	0.00
75%	19.60	22.75	18.41	6.56	0.00	11.85
50%	63.11	73.27	59.29	6.56	3.00	49.73
25%	174.90	203.06	164.33	6.56	3.00	154.77
10%	537.50	624.00	505.00	6.56	3.00	495.44

Priority HUC12s

Although this TMDL does require implementation of point source treatment improvements, reductions in nonpoint sources from BMP implementation in those HUC12s most impacted by TP loading will be necessary to achieve the TMDL (**Figure 44**; **Table 26**). The Delaware River TMDL Watershed consists of 25 HUC12s. According to STEPL the average amount of TP loading for the watershed is contributing 2.26 pounds per acre per year (lbs/acre/year). The high priority HUC12s are: 102701030308, 102701030203, and 102701030201 which all contribute 2.92 pounds per acre per year (lbs/acre/year) or more. Reductions in nonpoint sources will be the primary source of TP load reduction in this watershed. Implementation of BMPs in these priority HUC12s should reduce the main source of TP loading.

Figure 44. Map of priority HUC12s by total phosphorus load according to estimations from the Spreadsheet Tool for Estimating Pollutant Load for the Delaware River above Perry Lake TMDL Watershed.

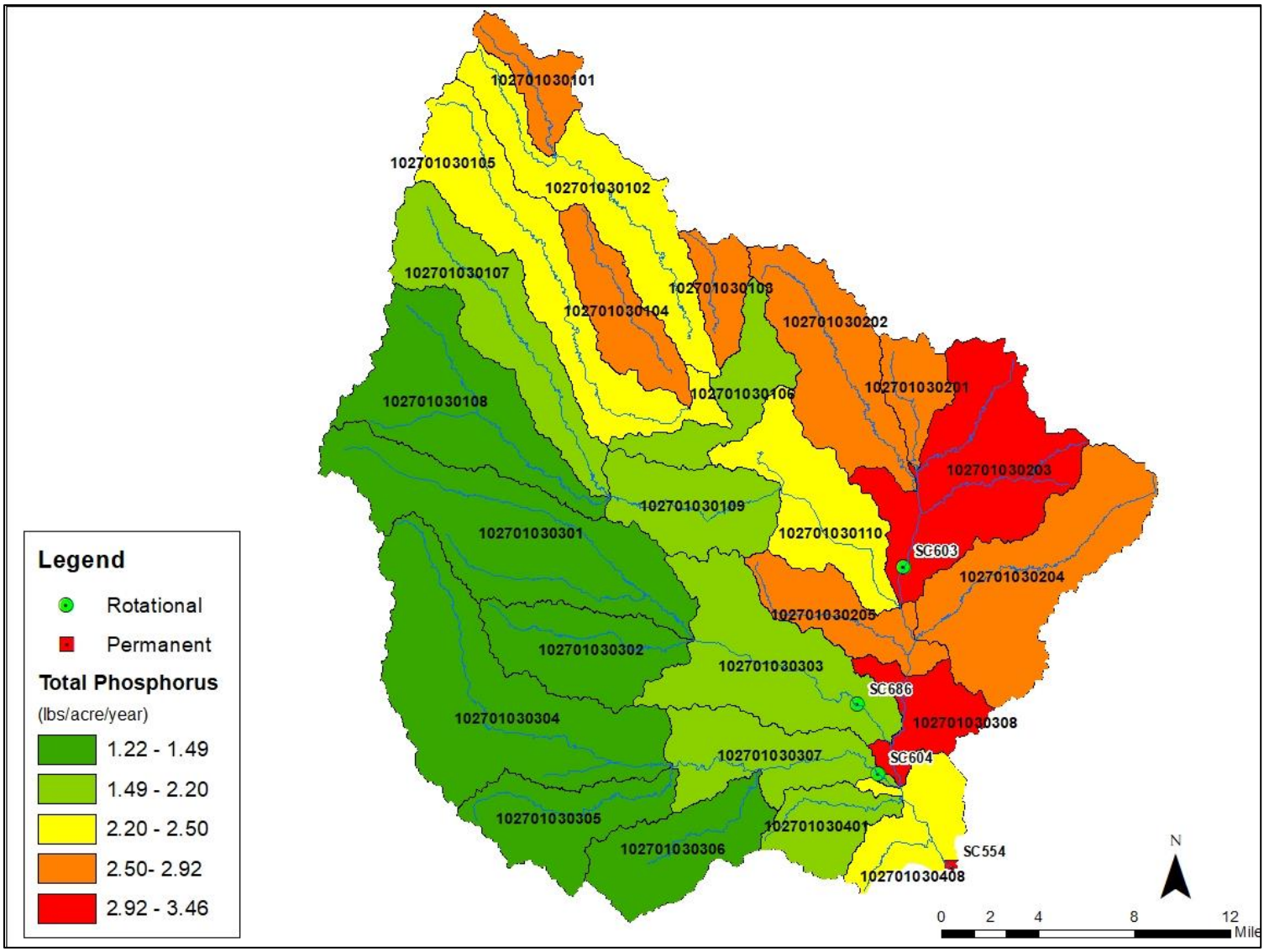


Table 26. Priority HUC12s by total phosphorus load according to estimations from the Spreadsheet Tool for Estimating Pollutant Load for the Delaware River above Perry Lake TMDL Watershed.

Watershed	Total Phosphorus (lbs/year)	Total Phosphorus (lbs/year/acre)	Total Nitrogen (lbs/year)	Total Nitrogen (lbs/year/acre)
102701030101	18,974.52	2.86	78,754.51	11.89
102701030102	58,912.90	2.5	254,625.58	10.8
102701030103	15,286.59	2.61	67,071.09	11.46
102701030104	29,328.09	2.63	123,959.93	11.13

Watershed	Total Phosphorus (lbs/year)	Total Phosphorus (lbs/year/acre)	Total Nitrogen (lbs/year)	Total Nitrogen (lbs/year/acre)
102701030105	67,446.01	2.42	298,425.51	10.69
102701030106	20,694.56	1.97	105,406.47	10.04
102701030107	42,226.72	1.92	208,193.54	9.45
102701030108	39,375.77	1.45	233,096.69	8.57
102701030109	31,451.97	2.18	150,058.94	10.4
102701030110	43,682.62	2.48	196,668.89	11.16
102701030201	**16,766.28**	**2.92**	**70,937.30**	**12.37**
102701030202	55,655.96	2.67	240,940.94	11.56
102701030203	**100,060.70**	**3.3**	**408,419.95**	**13.46**
102701030204	79,304.16	2.73	346,692.02	11.95
102701030205	31,332.10	2.82	134,321.72	12.11
102701030301	46,984.84	1.33	298,593.11	8.45
102701030302	22,306.49	1.4	136,889.16	8.6
102701030303	57,051.71	2.2	276,866.83	10.67
102701030304	56,459.70	1.4	341,541.48	8.47
102701030305	17,293.87	1.22	116,923.81	8.28
102701030306	22,248.94	1.49	131,592.54	8.81
102701030307	30,098.28	2.01	155,786.67	10.38
102701030308	**29,472.97**	**3.46**	**117,814.84**	**13.84**
102701030401	18,493.21	2.16	88,186.22	10.3
102701030408	43,702.29	2.37	200,981.37	10.89
Average	**39,784.45**	**2.26**	**191,309.96**	**10.63**

Definitions: **Priority HUC12s**

State Water Plan Implementation Priority

Due to the prevalence of high TP concentrations in the Delaware River and its tributaries, this TMDL initially focuses on reducing TP loading from nonpoint sources through effective riparian and land management in agricultural areas. Because this watershed drains to Perry Lake, a eutrophic lake that serves as a primary source of drinking water, this TMDL will be **High Priority** for implementation.

Nutrient Reduction Framework Priority Ranking

This watershed lies within the Delaware Subbasin (HUC8 10270103) which is among the top 16 HUC8s targeted for state action to reduce nutrients.

5. IMPLEMENTATION

Desired Implementation Activities

1. Make operational changes in municipal wastewater treatment plants and implement alternative disposal such as irrigation and, if necessary, install enhanced nutrient reduction technology to reduce wasteloads.
2. Renew state and federal permits and inspect permitted facilities for permit compliance.
3. Improve riparian conditions along stream systems by installing grass and/or forest buffer strips along the streams and drainage channels in the watershed.
4. Implement and maintain conservation farming practices—including conservation rotation, no-till farming, and contour farming—in order to reduce runoff and cropland erosion of agricultural areas in the watershed.
5. Perform extensive soil testing to ensure excess phosphorus is not unnecessarily applied.
6. Ensure labeled application rates for chemical fertilizers are followed to reduce runoff.
7. Implement nutrient management plans and ensure that land-applied manure is properly managed to reduce runoff.
8. Establish pasture management practices, including proper stock density, to reduce soil erosion and storm runoff.
9. Ensure proper on-site waste system operations in proximity to main stem and tributary segments.
10. Install alternative livestock watering systems and relocate livestock feeding areas away from riparian areas.
11. Establish alternative livestock foraging areas, collaborate with producers to develop areas for grazing cover crops, and implement rotational grazing systems.
12. Provide education and outreach opportunities on topics such as soil health, nutrient management, and livestock management.
13. Support BMP implementation efforts of the Delaware River Watershed Restoration and Protection Strategy (WRAPS).
14. Reduce erosion and sediment loading to streams through BMP implementation in targeted areas of the watershed.
15. Implement small-scale streambank stabilization including green infrastructure on adjacent land.
16. Implement riparian corridor livestock project in Grasshopper Creek.

Implementing these practices will reduce nutrient loading in the Delaware River; however, an emphasis on agricultural BMPs will be needed in this watershed in order to address nonpoint sources of loading and meet Phase I of this TDML (**Table 27**).

Table 27. Nonpoint source load reduction required to meet the Phase I TMDL for the Delaware River Watershed above Perry Lake for base flow conditions.

Station	Current Condition (lbs/year)	Load Capacity (lbs/year)	Wasteload Allocation (lbs/year)	Load Allocation Reduction (lbs/year)	Load Allocation Reduction (%)
Delaware River near Half Mound (SC554)	26,744	25,995	3,672	4,420	17

NPDES and State Permits – KDHE

a. Monitor influent into and effluent from the discharging permitted wastewater treatment facilities, continue to encourage wastewater reuse and irrigation disposal and ensure compliance and proper operation to control phosphorus levels in wastewater discharges.
b. Establish TP concentration goal of 1.0 mg/L for all mechanical municipal wastewater treatment facilities in accordance with the WLA.
c. Continue to monitor, ensure compliance, and confirm proper operation of wastewater facilities in this watershed
d. Manage the WLA for the watershed to accommodate growth as needed.
e. Manure management plans, detailing proper land application rates and practices, will be implemented to prevent runoff of applied manure.
f. Inspect permitted livestock facilities to ensure compliance.
g. Inspect new permitted livestock facilities for integrity of applied pollution prevention technologies.
h. Apply pollution prevention technologies to new registered livestock facilities with less than 300 animal units.

Nonpoint Source Pollution Technical Assistance – KDHE

a. Support Section 319 implementation projects for nutrient management through reduction of phosphorus runoff from agricultural activities.
b. Provide technical assistance on practices to establish vegetative buffer strips.
c. Support implementation efforts of the Delaware River WRAPS, and incorporate long term objectives of this TMDL into their 9-element watershed plans.
d. Provide technical assistance on nutrient management for livestock facilities and practices which minimize impacts of small livestock operations in the watershed to reduce impacts to stream resources.

Water Resource Cost Share and Nonpoint Source Pollution Control Program – KDA-DOC

a. Apply conservation farming practices—including no-till, terraces, and contours—and erosion control structures, including sediment control basins and constructed wetlands.
b. Provide sediment control practices to minimize erosion and sediment transport from cropland and grassland in the watershed.
c. Encourage residue management to reduce phosphorus loss and transport from cropland runoff in the watershed.
d. Implement manure management plans.
e. Install livestock waste management systems for manure storage.

Riparian Protection Program – KDA-DOC

a. Protect, establish, or re-establish natural riparian systems, including vegetative filter strips and streambank vegetation.
b. Develop riparian restoration projects along targeted stream segments, especially those areas with baseflow.

c. Promote wetland construction to reduce runoff and assimilate loadings.
d. Coordinate riparian management within the watershed and develop riparian restoration projects.

Buffer Initiative Program – KDA-DOC

a. Install grass buffer strips near streams.
b. Leverage Conservation Reserve Enhancement Programs to hold riparian land out of production.

Extension Outreach and Technical Assistance – Kansas State University

a. Educate agricultural producers on sediment, nutrient, and pasture management.
b. Provide technical assistance on buffer strip design and minimizing cropland runoff.
c. Encourage annual soil testing to determine capacity of field to hold phosphorus.
d. Educate residents, landowners, and watershed stakeholders about nonpoint source pollution.
e. Promote and utilize the WRAPS efforts for pollution prevention, runoff control, and resource management.
f. Educate livestock producers on livestock waste management, land applied manure applications, and nutrient management planning.
g. Provide technical assistance on livestock waste management systems and nutrient management planning.
h. Repair or replace failing septic systems which are located within 100 feet of the Delaware River or its tributaries.

Timeframe for Implementation

There are no major dischargers in this watershed. Reduction strategies will begin by 2021 to ensure nutrients are being addressed. Achieve project goals and objectives from WRAPS grant for Delaware River Watershed by end of funding cycle in 2023. Pollutant reduction practices should be installed within the watershed before 2025 with follow up implementation over 2025-2029. Phase I of this TMDL will occur from 2021 to 2040. If biology in the Delaware River Watershed above Perry Lake has not responded to Phase I reductions by 2040 then Phase II implementation will commence in 2040.

Targeted Participants

The primary participants for implementation of this TMDL are nonpoint sources of nutrients and Delaware River WRAPS. Agricultural operations immediately adjacent to the Delaware River and its tributaries will be encouraged to implement appropriate practices to further reduce phosphorus loads. Watershed coordinators, technical staff of the WRAPS group, conservation district personnel, and county extension agents should coordinate to assess possible nutrient sources adjacent to streams. Implementation activities to address nonpoint sources should focus on those areas with the greatest potential to impact nutrient loading to the river.

Targeted agricultural activities to focus attention toward include:

1. Reduce erosion and sediment loading to streams through BMP implementation in targeted areas of the watershed.
2. Implement small-scale streambank stabilization including green infrastructure on adjacent land.
3. Implement riparian corridor livestock project in Grasshopper Creek.
4. Nutrient management and green infrastructure in targeted areas.
5. Demonstrate innovative agricultural equipment to reduce nutrient runoff from cropland
6. Implement a general information and education program
7. Denuded riparian vegetation and poor riparian areas along the stream.
8. Conservation compliance on highly erodible areas.
9. Unbuffered cropland adjacent to the stream.
10. Total row crop acreage and gully locations.
11. No till or residue management on cropland.
12. Increasing no-till and precision agricultural practices, including cover crops and other soil health strategies.
13. Sites where drainage runs through or adjacent to livestock areas.
14. Sites where livestock have full access to the stream and it is their primary water supply.
15. Overused grazing land adjacent to the streams.

Milestone for 2026

The Delaware River WRAPS is beginning a three-year funding cycle to mitigate nutrient and sediment loads to the watershed, as well. This initiative seeks to reduce livestock impacts in the Grasshopper Creek and implement agricultural BMPs over this time frame. By 2026, advancement of necessary and appropriate measures to decrease the contribution of nonpoint sources of phosphorus loading to the TMDL watersheds should be in progress. At that point in time, TP data from the SC sites in the Delaware River watershed above Perry Lake should show indication of declining TP concentrations relative to the pre-2020 data, particularly during normal and lower flow conditions.

Delivery Agents

The primary delivery agents for program participation will be KDHE and the Delaware River WRAPS.

Reasonable Assurances

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution:

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.
2. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.
3. K.S.A. 2002 Supp. 82a-2001 identifies the classes of recreation use and defines impairment for streams.

4. K.A.R. 28-16-69 through 71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.
5. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation, and management of soil and water resources in the state, including riparian areas.
6. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control nonpoint source pollution.
7. K.S.A. 82a-901, et. seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.
8. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan,* including selected WRAPS.
9. The *Kansas Water Plan* provides the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

Funding: The State Water Plan annually generates $12-13 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watershed and water resources by priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL are located within a **High Priority** area and should receive support for pollution abatement practices that lower the loading of sediment and nutrients.

Effectiveness: Agricultural nutrient control has been proven effective through conservation tillage, contour farming, and use of grass waterways and buffer strips; additionally, the proper implementation of comprehensive livestock waste management plans has proven effective at reducing nutrient runoff associated with livestock facilities.

6. MONITORING

Monitoring will continue at KDHE stations for TP on a permanent basis with quarterly samples for Delaware River near Half Mound (SC554) and on a rotational basis with quarterly samples for Grasshopper Creek near Muscotah (SC603), Elk Creek near Larkinburg (SC604), and Straight Creek near Larkinburg (SC686). Monitoring will include summer sestonic chlorophyll *a* sampling and dissolved oxygen and pH levels will be assessed for indications of heightened primary productivity. Biological monitoring will also continue for the biology stations in this watershed SB360, SB352, and SB407, SB408 to assess compliance with the narrative nutrient criteria.

As the Phase I TP milestone of 0.209 mg/L TP is approached in Delaware River (SC554), Grasshopper Creek (SC603), Elk Creek (SC604), and Straight Creek (SC686), macroinvertebrate

sampling will be conducted and examined for signs of favorable responses in the aquatic community. Should the biological community fail to respond, Phase II implementation will commence with a TP milestone of 0.174 mg/L in all stream chemistry stations in this TMDL.

Once the biological endpoints are achieved, the conditions described by the narrative nutrient criteria will be viewed as attained and Delaware River near Half Mound (SC554), Grasshopper Creek near Muscotah (SC603), Elk Creek near Larkinburg (SC604), and Straight Creek near Larkinburg (SC686) will be considered for delisting. Once the water quality standards are attained, the adjusted ambient phosphorus concentrations will be the basis for establishing numeric phosphorus criteria through the triennial water quality standards process.

7. FEEDBACK

Public Notice

An active website is established at http://www.kdheks.gov/tmdl/planning_mgmt.htm to convey information to the public on the general establishment of TMDLs and to provide specific TMDLs by river basin. This TMDL was posted to the Kansas-Lower Republican River Basin on this site on August 22, 2019 for public review.

Public Hearing

A public hearing on this TMDL was held on September 6th, 2019 in Topeka, Kansas to receive public comments. No comments were received.

Milestone Evaluation

In 2030, evaluation will be made as to the degree of implementation that occurred within the watershed. Subsequent decisions will be made through consultation with local stakeholders and the WRAPS team regarding implementation of nonpoint source reduction strategies and development of additional implementation strategies for the watershed.

Consideration for 303(d) Delisting

The Delaware River and its tributary segments covered by this TMDL will be evaluated for delisting under Section 303(d) based on the monitoring data from 2020 to 2030. Therefore, the decision for delisting will ensue in the preparation for the 2032 Section 303(d) list. Should modifications be made to the applicable water quality criteria during the implementation period, consideration for delisting, desired endpoints of this TMDL, and implementation activities may be adjusted accordingly.

Incorporation into the TMDL Vision Process, Water Quality Management Plan, and the Kansas Water Planning Process

Under the current version of the Kansas TMDL Vision Process, the next anticipated revision of this TMDL will be after 2024. The revision will emphasize implementation of WRAPS activities and further reduction of nutrients in wastewater discharged by NPDES facilities.

Recommendations for this TMDL will be considered in the *Kansas Water Plan* implementation decisions under the State Water Planning Process for fiscal years 2020 to 2030.

Developed: September 24, 2019.

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